5

HOW IT WORKS

AMAZING GEOGRAPHY

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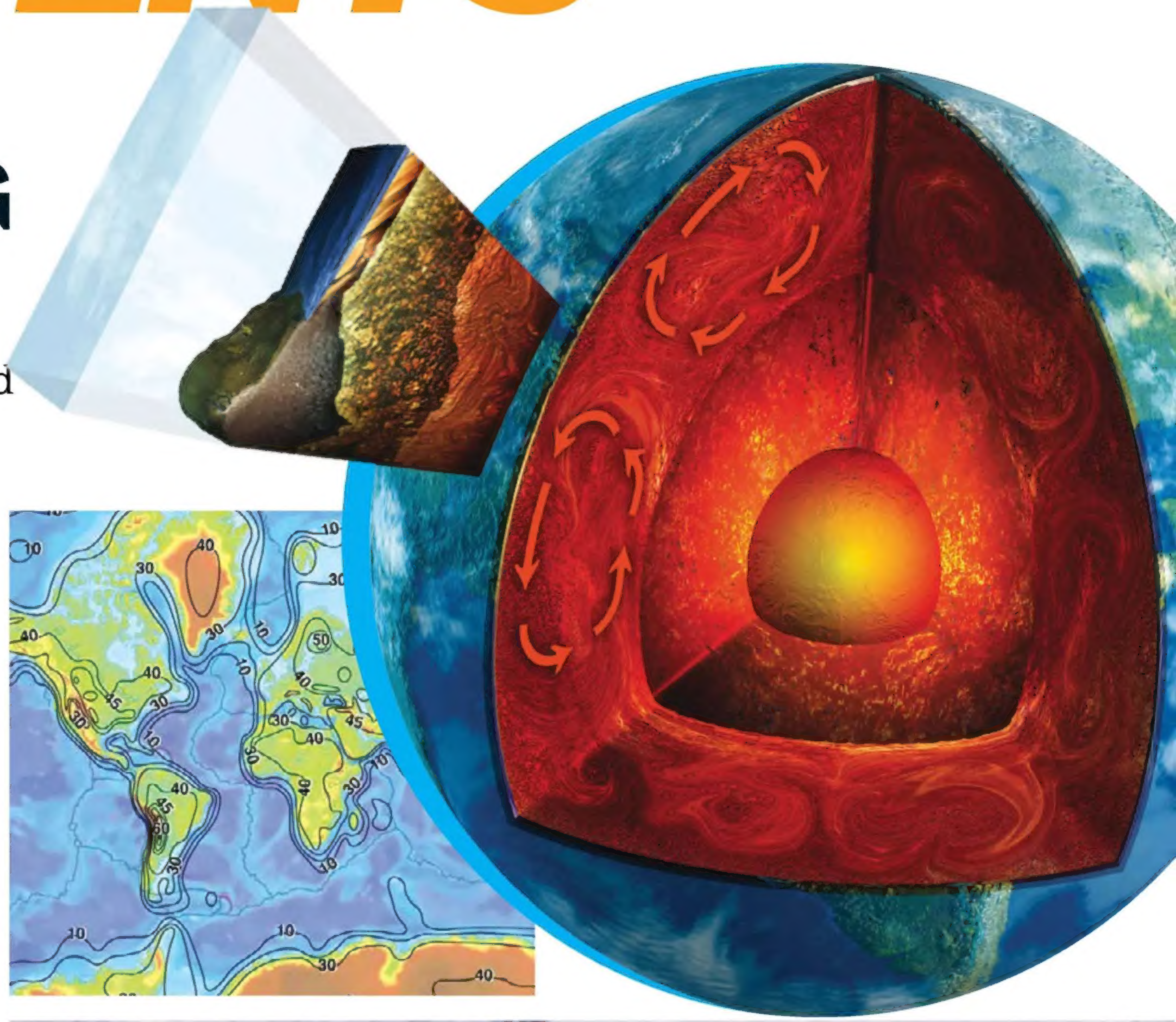

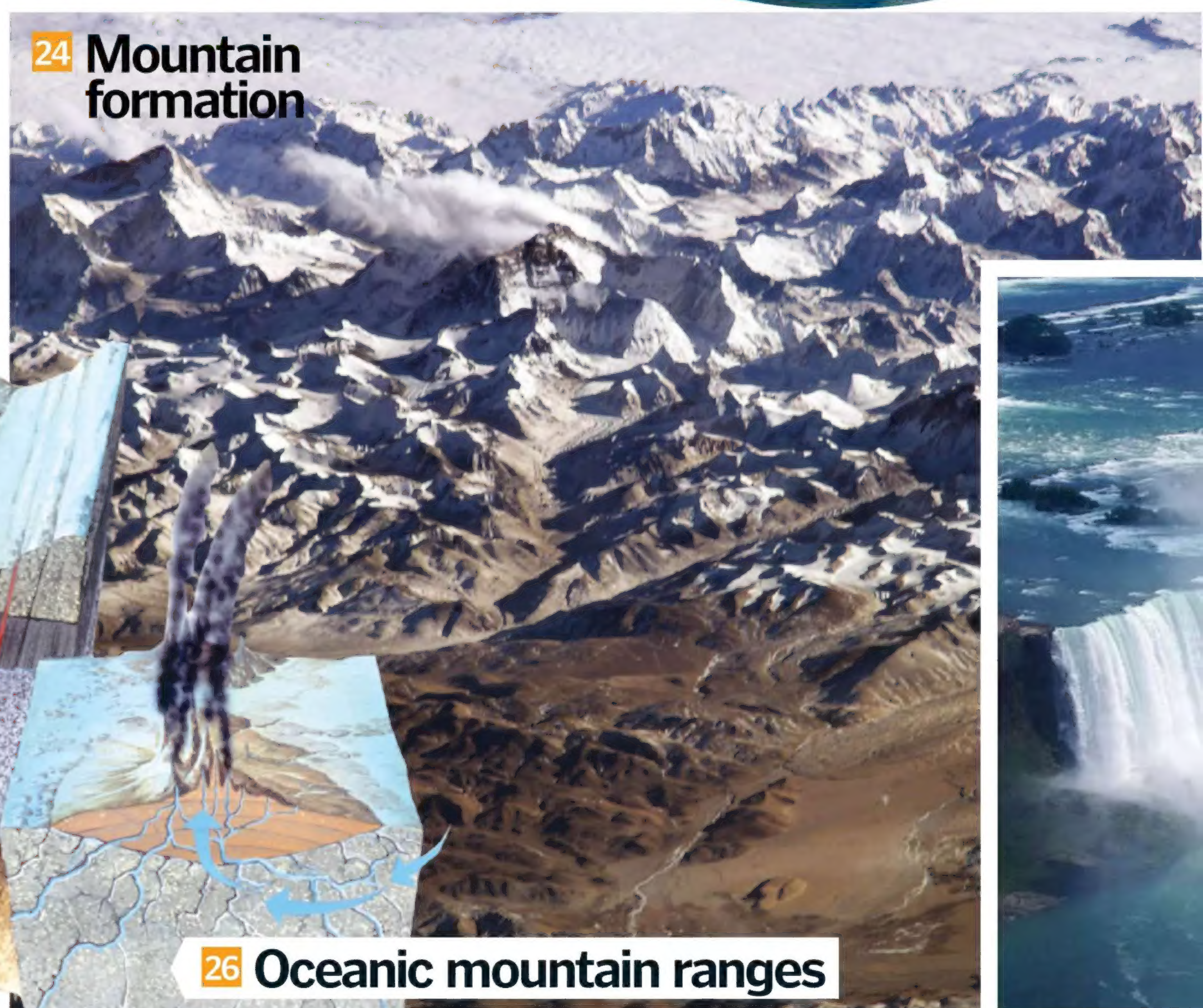

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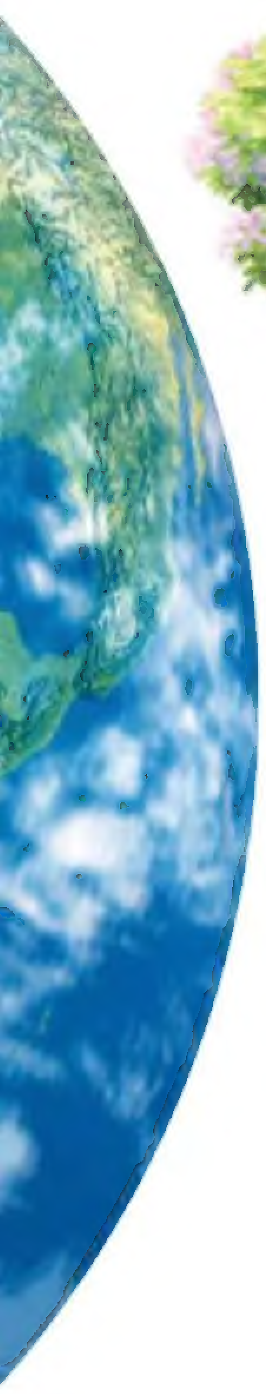
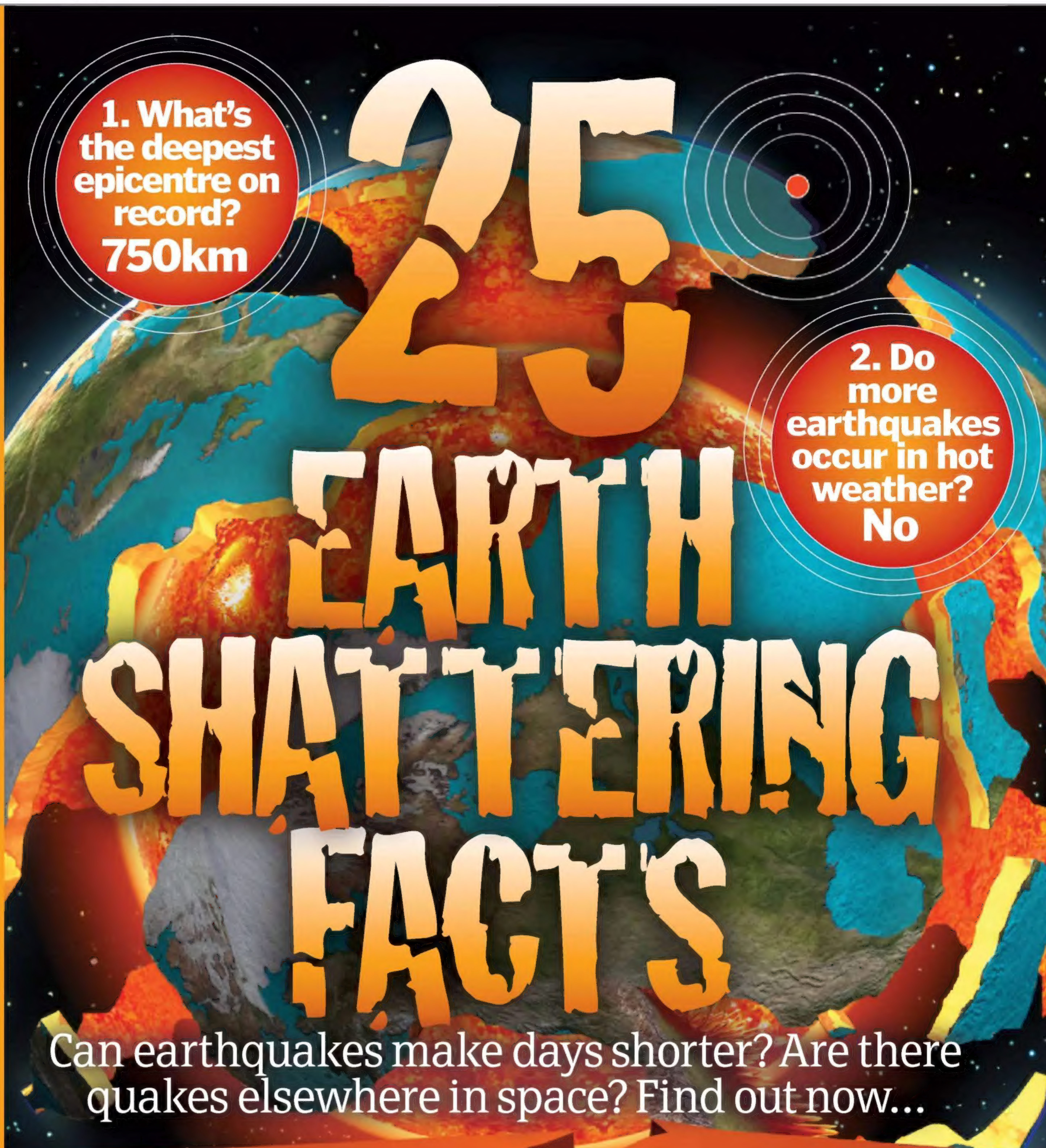




25 Earth Shattering Facts

Can earthquakes make days shorter? Are there quakes elsewhere in space? Find out now…

The earthquake and tsunami that devastated north-east Japan in March 2011 demonstrate the terrifying power of these natural phenomena. Almost 16,000 people died and more than a million buildings wholly or partly collapsed.

A year after the event, 330,000 people were still living in hotels or in other temporary accommodation, unable to return home. A further 3,000 people were still listed as missing. The gigantic tsunami waves spawned by the earthquake inundated the power supply and cooling of three reactors at the Fukushima Daiichi power station. The subsequent nuclear accident – the worst since Chernobyl – caused worldwide panic.

Earthquakes are unstoppable and strike with little or no warning, but we know a growing amount about how they work. Scientists have developed networks of sensors for monitoring ground movements, changes in groundwater and magnetic fields, which may indicate an impending quake. Engineers, meanwhile, have created new forms of architecture to resist earthquakes when they do strike. So without further ado, let's learn some earth-shattering facts…

5 TOP FACTS
QUAKE PROOFING

Cloaking device
1 A 'cloak' of concentric plastic rings could protect future buildings from quakes. Waves of vibrations would be diverted in an arc around the building, saving it from damage.

Get braced
2 Engineers strengthen buildings against twisting forces by building around a skeleton of diagonal crossbeams, vertical shear walls and steel frames.

Steeling up
3 Buildings made of structural steel or reinforced with steel beams are less brittle than unreinforced brick or concrete buildings, and can flex when swayed by an earthquake.

Rubber feet
4 The building sits on lead-rubber cylinders, bearings or springs. These sway horizontally when a quake hits to reduce the sideways movement of the structure.

Symmetry
5 Box-shaped buildings are more resistant than irregular-shaped ones, which twist as they shake. Each wing of an L or T-shaped building may vibrate separately, increasing damage.

DID YOU KNOW? *Antarctica gets icequakes, a kind of earthquake that occurs in the ice sheet*

3. What is Earth's crust made of?

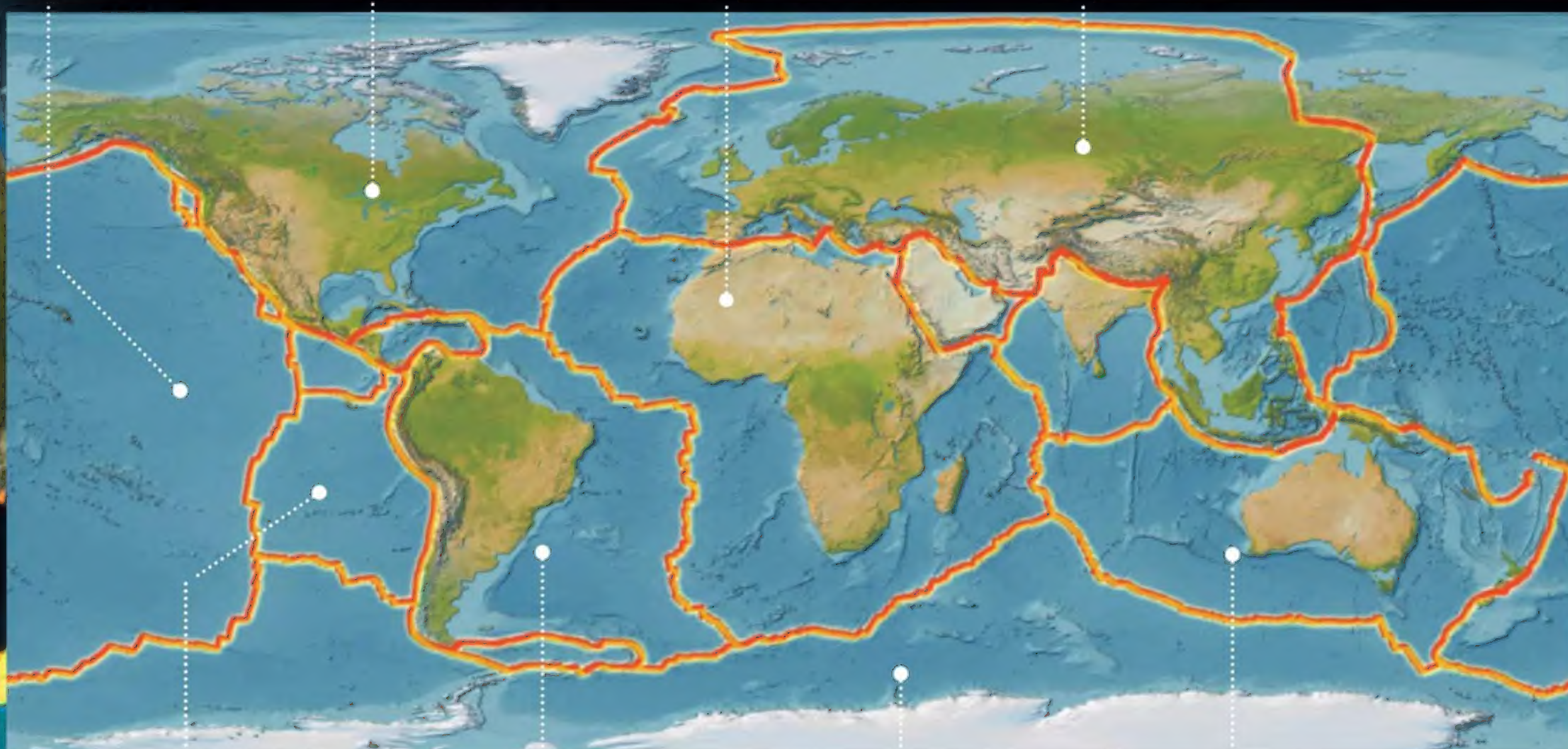
The crust consists of rock broken into moving slabs, called plates. These plates float on the denser rocks of the mantle, a sticky layer lying between the planet's core and the crust. Granite is the commonest rock in the crust that makes up Earth's continents. This continental crust is an average 35 kilometres (22 miles) thick, deepest beneath mountain ranges. Ocean floor crust is thinner – on average six kilometres (four miles) – and mainly made of denser volcanic rocks, such as basalt. Granite is 75 per cent oxygen and silicon. Basalt is denser as the silicon is contaminated with heavier elements like iron.

Pacific Plate
Earth's biggest plate is among the fastest moving, travelling north-west some seven centimetres (three inches) annually.

North American Plate
The continent of North America and some of the Atlantic Ocean floor sit on this plate.

African Plate
This plate carrying the African continent carries some of the world's most ancient crust – up to 3.6 billion years old.

Eurasian Plate
The Himalayas, Earth's highest mountain range, is rising as the Indian Plate thrusts beneath the Eurasian Plate.



Nazca Plate
The Nazca Plate located off South America's west coast is one of several smaller plates.

South American Plate
The collision of South America with the Nazca Plate is lifting up the Andes, our planet's longest mountain range.

Antarctic Plate
Until 45 million years ago, the Antarctic Plate was joined to the Australian Plate.

Indo-Australian Plate
The Indo-Australian Plate may be splitting apart to form separate Indian and Australian Plates.

4. Did the 2011 quake in Japan shorten the days on Earth?

Yes, but you're unlikely to notice. Every day is now 1.8 microseconds shorter, according to NASA. The Japan earthquake made Earth spin slightly faster by changing its rotation around an imaginary line called the figure axis. The Earth's mass is balanced around the figure axis, and it wobbles as it spins. That wobble naturally changes one metre (3.3 feet) a year due to moving glaciers and ocean currents. The 2011 Tohoku earthquake moved the ocean bed near Japan as much as 16 metres (53 feet) vertically and 50 metres (164 feet) horizontally – that's the equivalent horizontal distance to an Olympic swimming pool! The shifting ocean bed increased Earth's wobble around the figure axis by 17 centimetres (6.7 inches). As the wobble grew, Earth sped up its rotation. It's the same principle as when a figure skater pulls their arms closer to their body in order to spin faster.

5. What is the shadow zone of an earthquake?

A shadow zone is the location on the Earth's surface at an angle of 104-140 degrees from a quake's origin that doesn't receive any S-waves or direct P-waves. S and P-waves are seismic waves that can travel through the ground. Seismic waves are shockwaves created when a fault suddenly moves. The shadow zone occurs as S-waves can't pass through the Earth's liquid outer core, while P-waves are refracted by the liquid core.

6. Where is the quake capital?

Around 90 per cent of earthquakes occur on the so-called Ring of Fire, a belt of seismic activity surrounding the Pacific Plate. The Ring of Fire is a massive subduction zone where the Pacific Plate collides with and slides beneath several other crustal plates. Most earthquakes are measured in Japan, which lies on the Ring of Fire at the junction of the Pacific, Philippine, Eurasian and Okhotsk Plates. Japan has a dense earthquake-monitoring network, which means scientists can detect even small quakes. The volcanic island chain of Indonesia probably experiences the most earthquakes based on landmass, however it has fewer instruments for measuring them.

7. Are earthquakes more likely to occur in the morning? No

8 What are tremors?

A tremor is simply another word for an earthquake. It's also another word for the vibrations you experience when a quake hits. The earth trembles because movement energy is released in an earthquake, causing the ground to vibrate.

9 How can scientists tell how far away an earthquake occurred?

Scientists use a seismometer to record earthquake waves called P and S-waves. P-waves travel faster than S-waves and can pass through liquids. By measuring the delay between the P and S-waves arriving, they can calculate the distance the waves travelled.

10 What's the earliest recorded major earthquake in history?

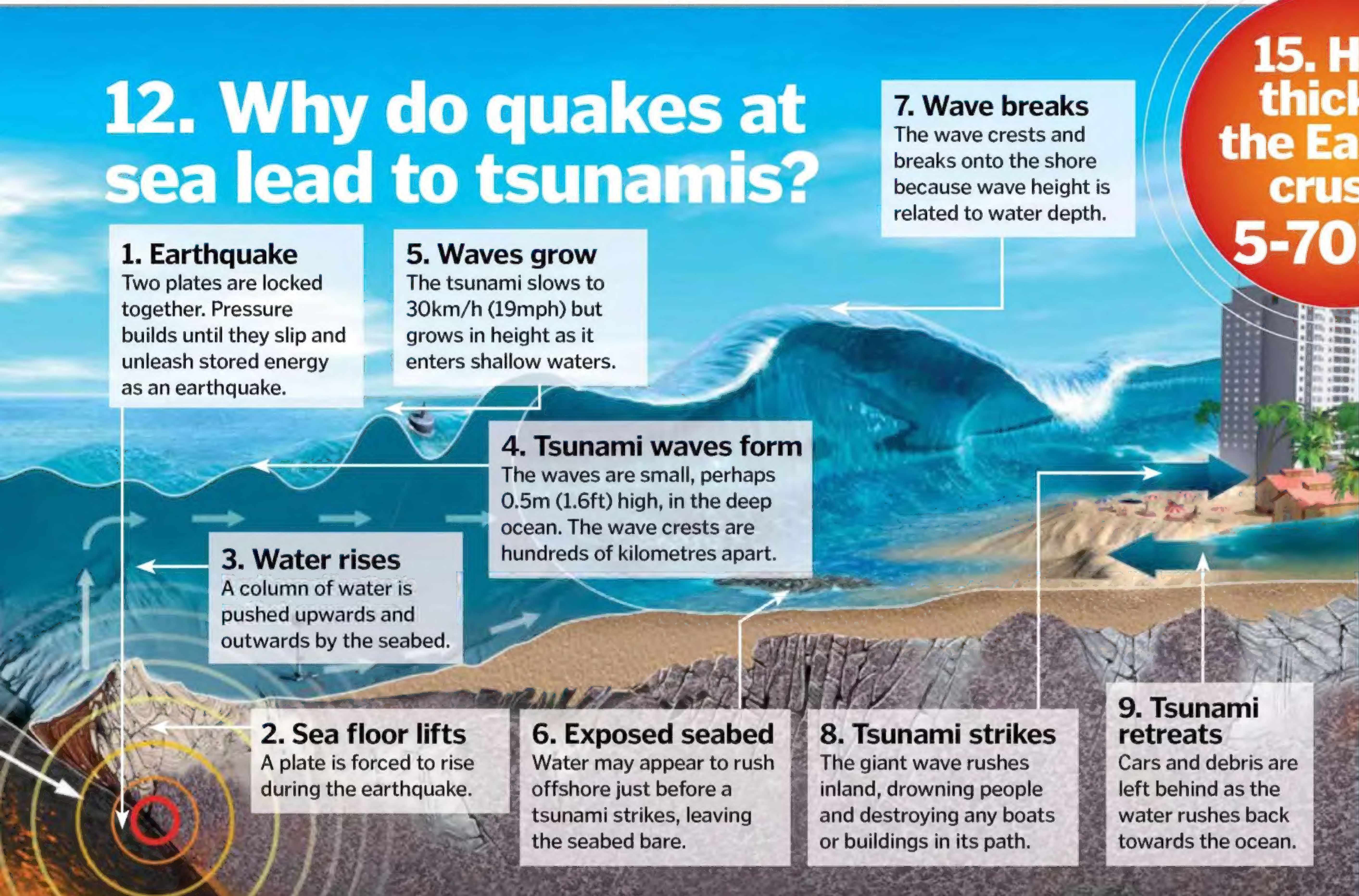
The first earthquake described was in China in 1177 BCE. By the 17th century, descriptions of the effects of earthquakes were published worldwide, although of course these accounts were often exaggerated and less detailed than data recorded today.

11 What do the lines on a seismometer reading represent?

The wiggly lines on a seismogram represent the waves recorded. The first big wiggles are P-waves. The second set of wiggles are S-waves. If the latter are absent, the quake happened on the other side of the planet.

“Seismometers on the Moon detected tidal ‘moonquakes’ caused by the pull of the Earth’s gravity”

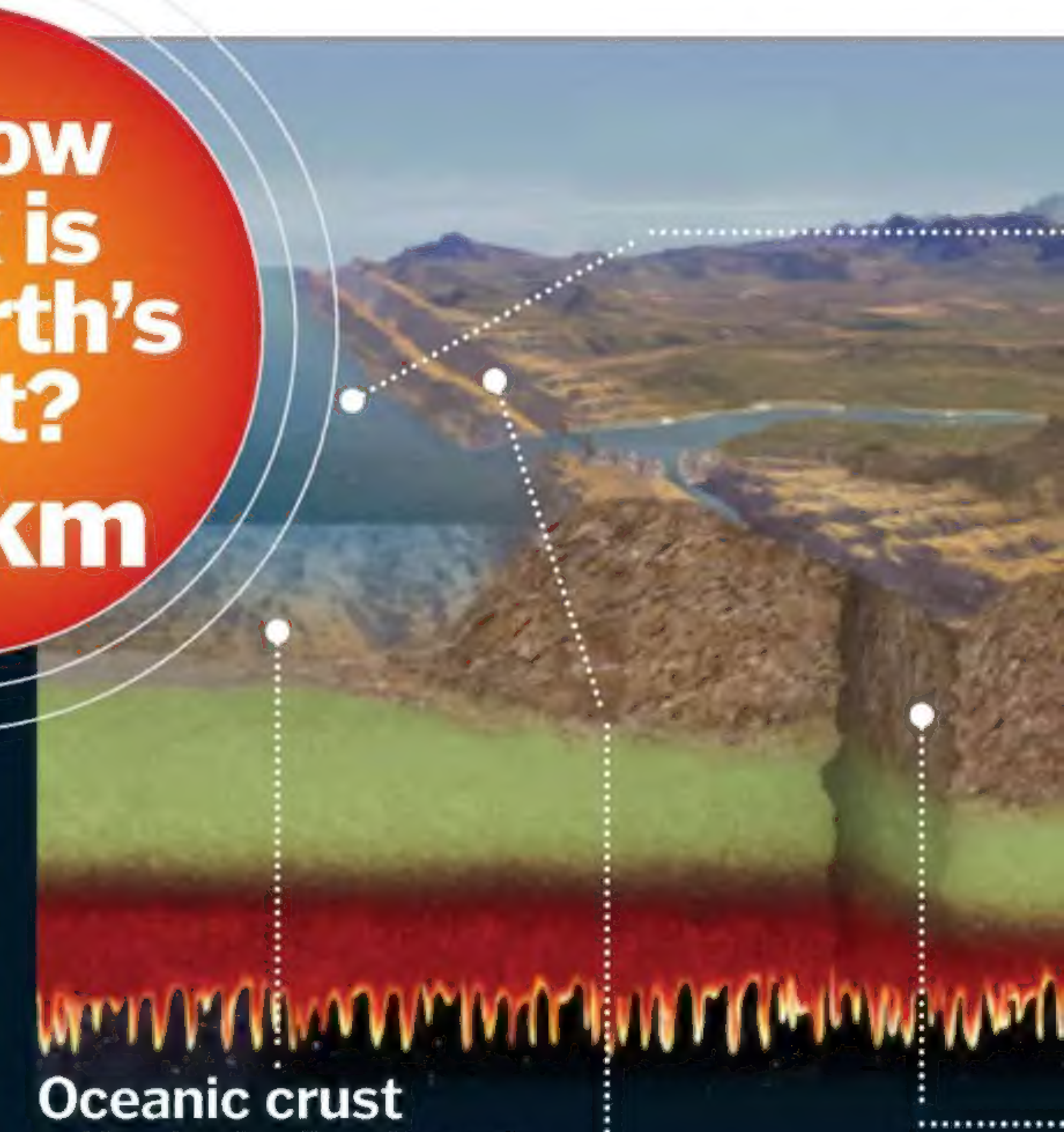
12. Why do quakes at sea lead to tsunamis?



Earthquakes trigger tsunamis by generating ripples, similar to the effect of sloshing water in a glass. Tsunamis are giant waves, which can cross oceans at speeds similar to jet aircraft, up to 700 kilometres (435 miles) per hour, and reach heights of 20 metres (66 feet) as they hit the coast. They sweep inland faster than running speed, carrying away people and buildings alike. For example, the 2004 Indian Ocean tsunami claimed 300,000 lives and made nearly 2 million more homeless.

15. How thick is the Earth’s crust?

5-70km



Oceanic crust
The Pacific Plate is mainly oceanic crust, which is younger and thinner than continental crust – about 5-10km (3-6mi) thick.

San Andreas Fault
The San Andreas is a strike-slip fault created by the Pacific and North American Plates sliding past each other.

16. How many quakes occur each year?

500,000

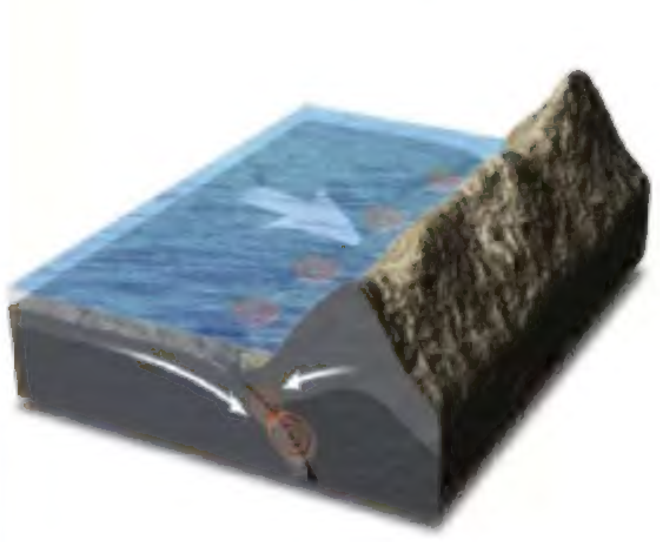
13. Are there different types of earthquake?

Strike-slip fault

Roads can be sheared apart along strike-slip faults. They’re straight cracks in the crust where two plates are sliding horizontally past each other. Every time a section of the fault moves, an earthquake occurs.

Normal fault

Earth’s brittle crust becomes fractured along fault lines. Quakes occur along a normal fault when the two sides move apart. Rock slabs sitting above the fault slide down in the direction the plates are moving, like at the Mid-Atlantic Ridge.



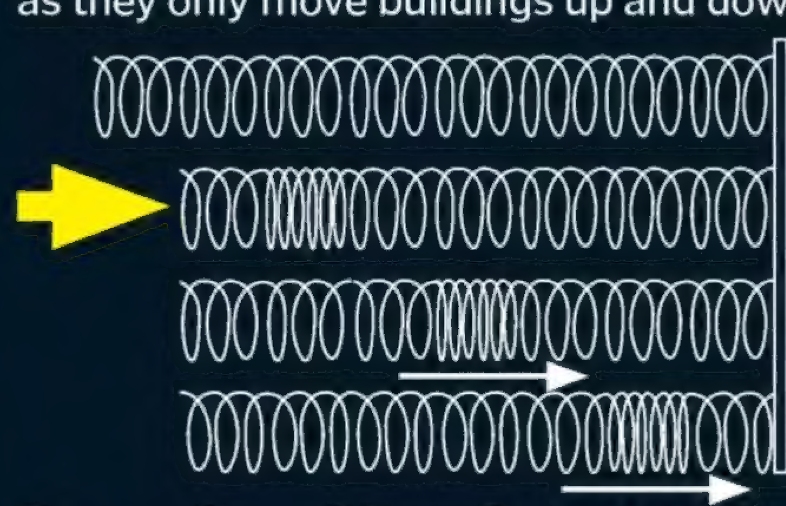
Thrust fault

The 2011 Tohoku quake ruptured a thrust fault in a subduction zone. These zones are associated with Earth’s most violent quakes as oceanic crust grinds beneath continental crust, creating great friction. Huge stresses can build here and release the same energy as a thousand hydrogen bombs!

14. How do P and S-waves move?

Primary (compressional) waves

P-waves are the fastest waves created by an earthquake. They travel through the Earth’s interior and can pass through both solid and molten rock. They shake the ground back and forth – like a Slinky – in their travel direction, but do little damage as they only move buildings up and down.



Secondary (shear) waves

S-waves lag behind P-waves as they travel 1.7 times slower and can only pass through solid rock. However they do more damage because they’re bigger and shake the ground vertically *and* horizontally.

17. Do earthquakes happen off Earth?

There’s evidence of ‘marsquakes’ on Mars as well as quakes on Venus. Several moons of Jupiter and Titan – a moon of Saturn – also show signs of quakes. Seismometers on the Moon detected tidal ‘moonquakes’ caused by the pull of the Earth’s gravity, vibrations from meteorite impacts and tremors caused by the Moon’s cold crust warming after the two-week lunar night.

HEAD 2 HEAD
BIGGEST QUAKES

1. BIG

Shaanxi, China, 1556 (mag 8.0)
Around 830,000 people died in this quake, which flattened city walls and was felt 800 kilometres (500 miles) away.

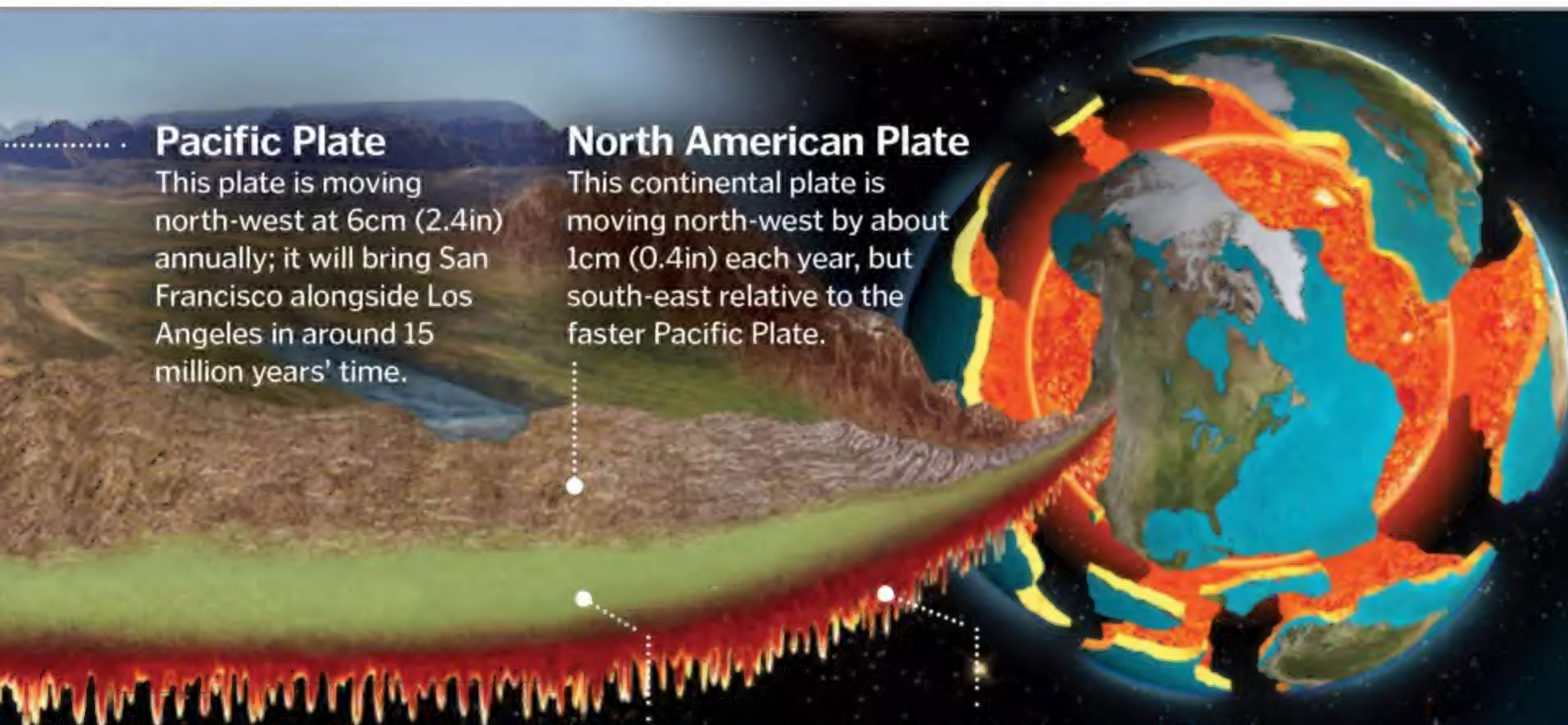
2. BIGGER

Tohoku, Japan, 2011 (mag 9.0)
Japan's biggest recorded earthquake killed 15,853 people, collapsed 129,874 buildings and triggered a global nuclear crisis.

3. BIGGEST

Valdivia, Chile, 1960 (mag 9.5)
The most powerful quake ever left 2 million people homeless and spawned a tsunami affecting Hawaii, Japan and the Philippines.

DID YOU KNOW? *Tidal waves and tsunamis are not the same; the former is brought on by gravitational, not seismic, activity*



18. Why is the San Andreas Fault prone to large quakes?

Longer faults have larger earthquakes, which explains why the strike-slip San Andreas Fault has had several quakes over magnitude 7. The San Andreas Fault extends 1,300 kilometres (800 miles) along the coast of California. When a fault ruptures, it 'unzips' along its length. Each section of the fault releases energy – the longer the fault, the more energy released and so the bigger the quake. Scientists believe the San Andreas Fault is overdue for a potential magnitude 8.1 earthquake over a 547-kilometre (340-mile) length. The southern segment has stayed static for more than a century, allowing enormous stresses to build.

19. Could Africa ever be split from Europe by an earthquake?

The Eurasian and African Plates are not splitting apart; they're actually moving towards each other at about one centimetre (0.4 inches) each year. In the future, it's possible that the Eurasian Plate may begin to slide beneath the African Plate. Even if the plates were moving apart, you'd need a mega-quake to yank Africa away from Europe in one go. There is no known fault long enough to create a mega-quake above magnitude 10. The most powerful earthquake in history was magnitude 9.5.

20. How many people jumping would it take to re-create the same reading as the Tohoku earthquake?

You'd need a million times Earth's population, all jumping at once, to generate the energy released by the March 2011 Tohoku quake. How do you calculate that? You assume Earth's population is 10 billion and each person generates 200 joules of energy by jumping 0.3 metres (0.98 feet).

23 Can animals predict quakes?

There's little evidence for whether animals can predict earthquakes, but many stories exist of odd behaviour. These include hibernating snakes fleeing their burrows in China in 1975, a month before the Haicheng quake.

24 Where is the safest place to be during an earthquake?

The safest place inside is underneath a sturdy table, away from light fittings and windows. The safest place outside is out in the open away from any buildings and electricity cables.

25 If I were stood on a beach during an earthquake would I sink?

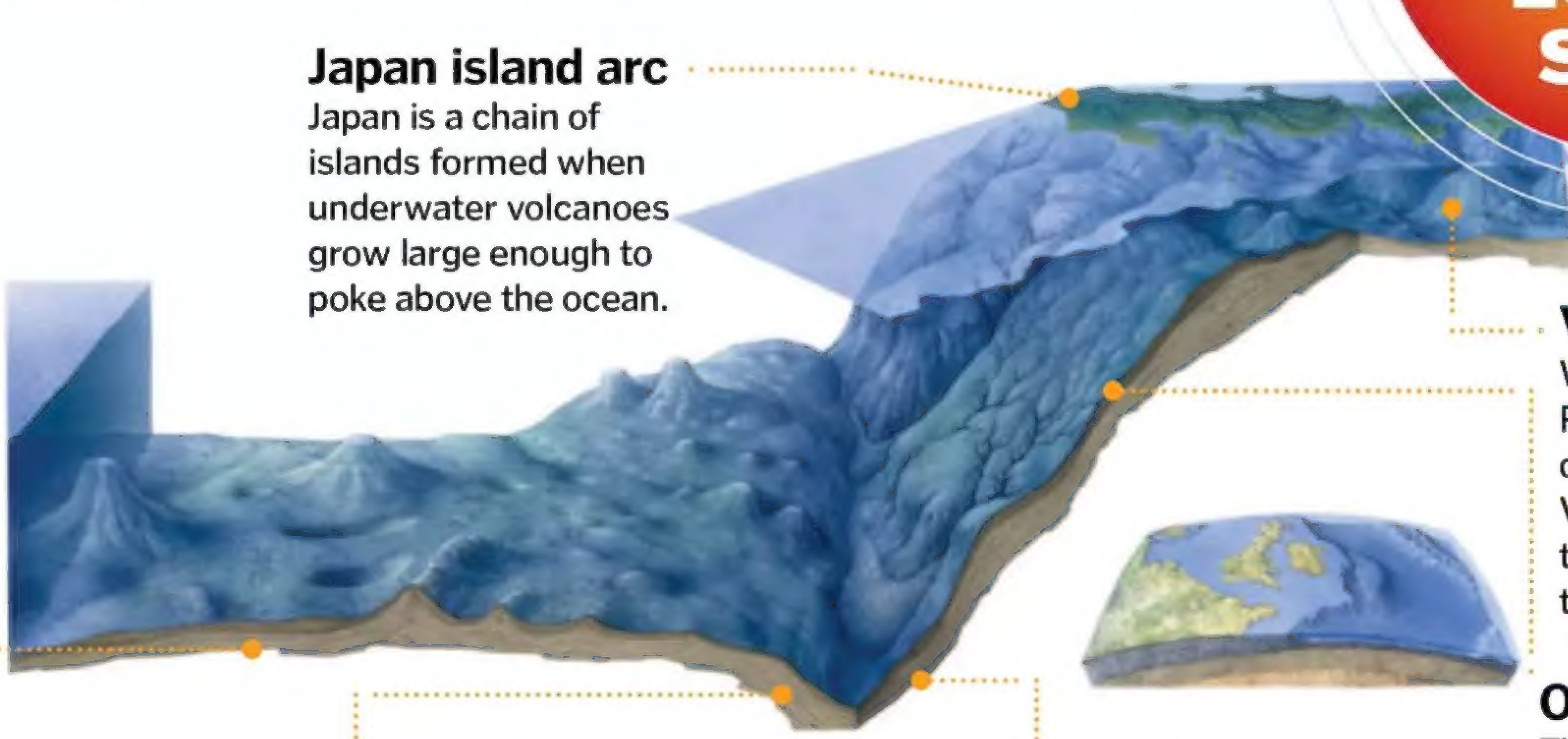
Perhaps, but it's unlikely you would drown. During an earthquake, wet sand or soil can behave like quicksand – a process called liquefaction. A quake vibrates the sand, separating the grains so that they flow like a liquid. It's extremely unusual and even then people will rarely sink below their chests during liquefaction as they will float.

21. How did the Japan Trench form?

A 390-kilometre (242-mile) stretch of the Japan Trench is associated with Japan's 2011 Tohoku earthquake. The trench is a vast chasm in Earth's crust at the junction between the Pacific Plate and tiny Okhotsk Plate beneath Japan. The Pacific Plate is moving westwards and diving beneath the Okhotsk. Friction between the two plates causes them to lock together and pressure to build. Sudden slippages release the tension in a violent burst of energy.

22. How long do quakes last?

10-30 secs



The Earth's

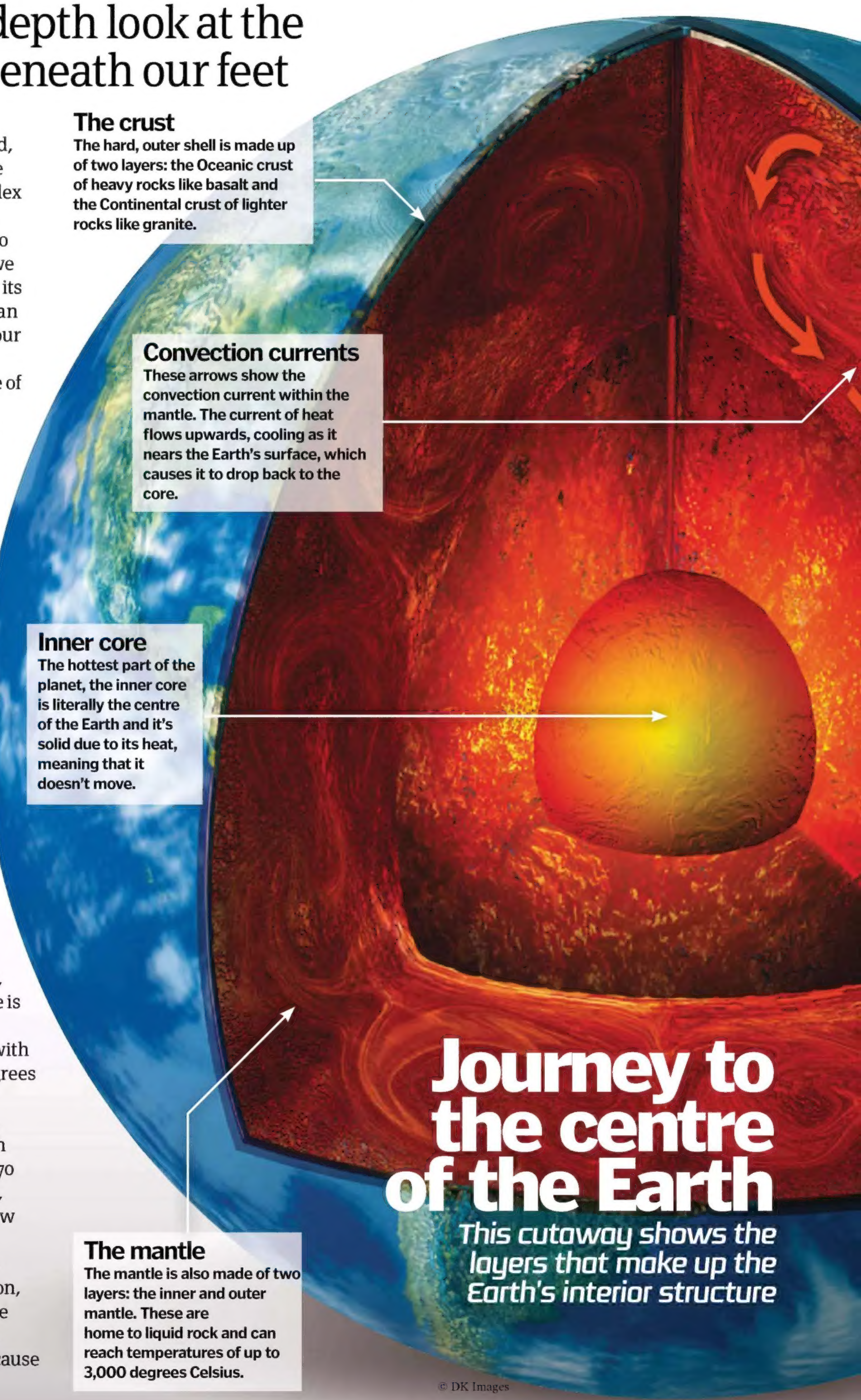
We take an in-depth look at the hidden world beneath our feet

We take the world around us for granted, but the Earth that we walk upon is a complex blend of layers that together create our planet. Thanks to research in the field of seismology, we now know the makeup of the Earth, its distances and measurements and can even compare it to other planets in our solar system.

Essentially, the internal structure of the Earth is made up of three core elements: the crust, the mantle and the core. The crust is the hard outer shell that we live on, split into Oceanic and Continental crusts, and it is comparatively thin. The first layer, the Oceanic crust, is around four to seven miles thick, made up of heavy rocks, whereas the lighter Continental crust is thicker, at approximately 19 miles.

Below the crust is the mantle, and again this is divided into two distinct layers: the inner and outer mantle. The outer mantle is the thinner of the two layers, occurring between seven miles and 190 miles below the Earth's surface. The outer mantle is made up of a bottom layer of tough liquid rock, with a temperature of somewhere between 1,400 degrees Celsius and 3,000 degrees Celsius, and a thinner, cooler upper layer. The inner mantle is deep into the Earth's structure, at between 190 and 1,800 miles deep, with an average temperature of 3,000 degrees Celsius.

Finally, we reach the Earth's core, which is 1,800 to 3,200 miles beneath our feet. The outer core is around 1,370 miles thick, encasing the inner core, which falls down to 3,960 miles below the Earth's surface. The inner core reaches a temperature high of 6,000 degrees Celsius and is made up of iron, nickel and other elements. While the outer core is liquid, the inner core is solid, and the two work together to cause the Earth's magnetism.



The crust
The hard, outer shell is made up of two layers: the Oceanic crust of heavy rocks like basalt and the Continental crust of lighter rocks like granite.

Convection currents
These arrows show the convection current within the mantle. The current of heat flows upwards, cooling as it nears the Earth's surface, which causes it to drop back to the core.

Inner core
The hottest part of the planet, the inner core is literally the centre of the Earth and it's solid due to its heat, meaning that it doesn't move.

The mantle
The mantle is also made of two layers: the inner and outer mantle. These are home to liquid rock and can reach temperatures of up to 3,000 degrees Celsius.

Journey to the centre of the Earth

This cutaway shows the layers that make up the Earth's interior structure

5 TOP FACTS EARTH'S AXIS

Day and night
1 During Earth's year-long orbit round the Sun, it also rotates once a day round its axis, an imaginary line passing through the North and South Poles, creating day and night.

The seasons
2 Earth's axis tilts at 23.5°. When Earth orbits the Sun, the North Pole spends six months leaning towards the Sun and six months leaning away from it.

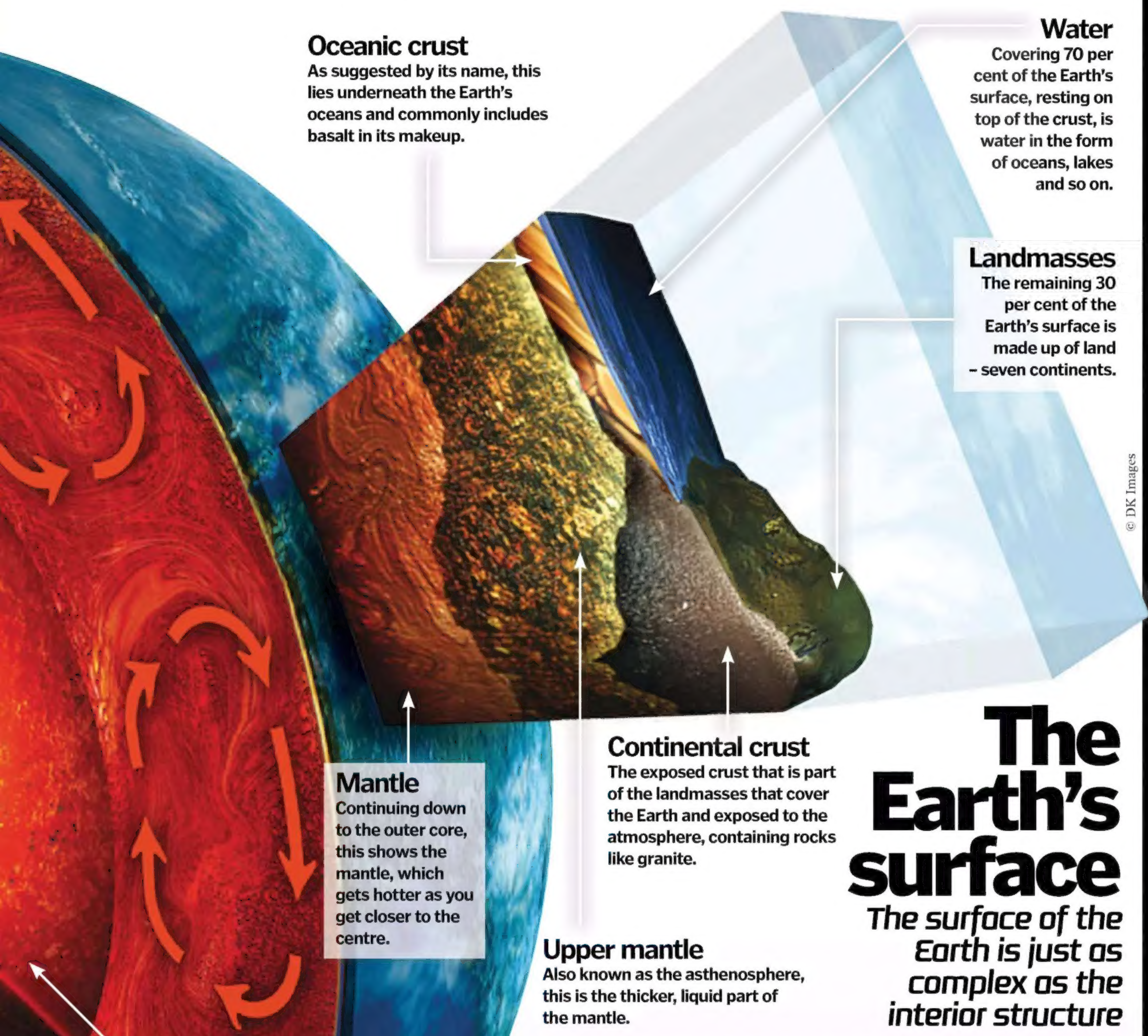
The tides
3 The Earth's tides are caused by the gravity of the Moon. The Earth's water on the side nearest to the Moon is pulled causing the water to bulge, this is known as a high tide.

Spring tide
4 The Sun also affects the tides, and when the Sun and Moon are aligned with the Earth, their combined gravities create the highest tide, called spring tide.

Neap tide
5 When the Sun and Moon are not lined up but are instead at right angles to each other, their gravities cancel each other out, creating the Earth's lowest neap tides.

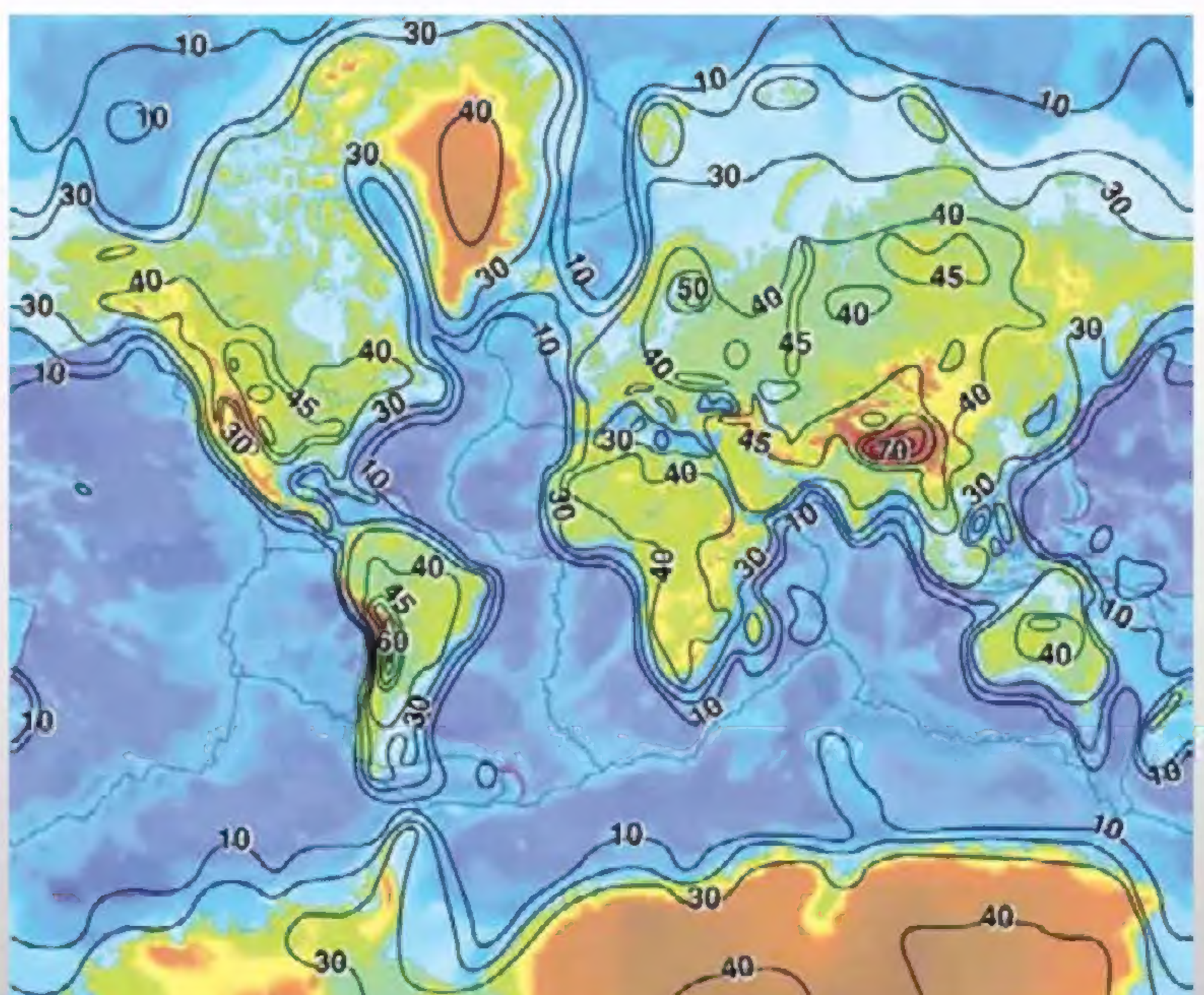
DID YOU KNOW? 70 per cent of the Earth's surface is covered in water

structure



The Earth's surface

The surface of the Earth is just as complex as the interior structure

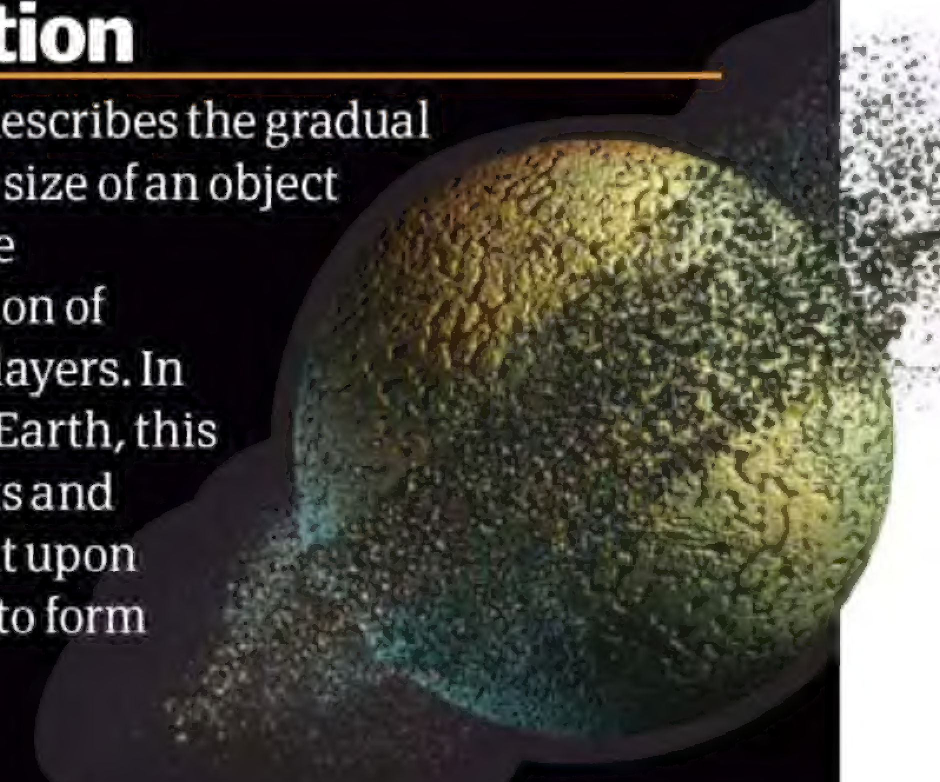


Crust thickness
A contour map of the globe, showing the thickness of the Earth's crust, with the numbers in kilometres.

How the Earth formed

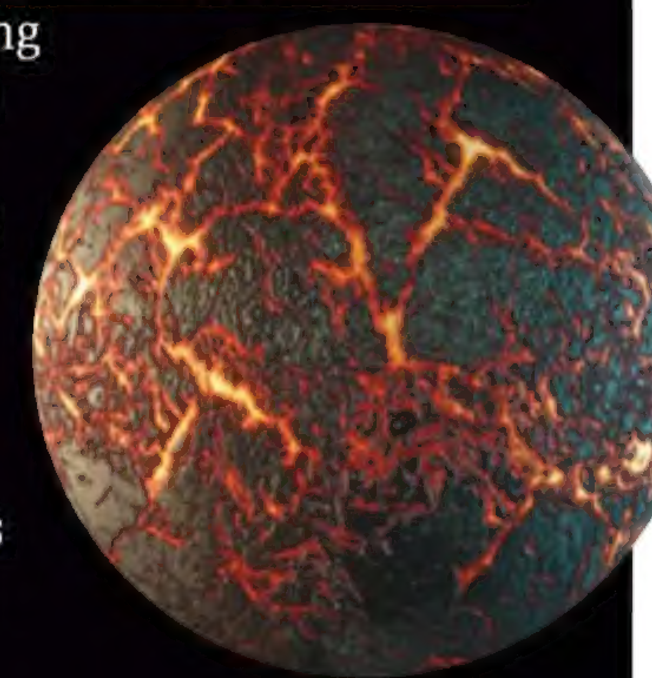
A complicated procedure brought together the many elements of the Earth and even today the planet is adapting and changing

Accretion



Accretion describes the gradual increase in size of an object through the accumulation of additional layers. In the case of Earth, this is how rocks and metals built upon each other to form the core.

Heating and cooling

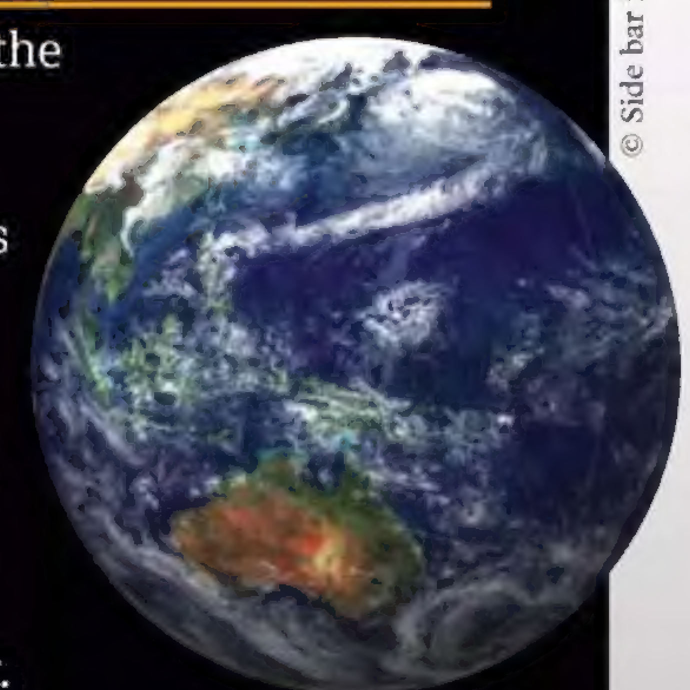


The process of creating planets via accretion causes friction and collisions that create a heat, which partly explains the temperature at the Earth's core. As this cooled in the planet's formation, the crust hardened.

Oceans and atmosphere

Steam from the crust combined with gases from volcanoes to create the atmosphere and water. As the planet cooled, clouds formed, causing rain, which in turn caused the oceans.

Today's Earth



Though we rarely see the results, the Earth's surface continues to change as landmasses collide and break apart, thanks to the dynamic properties of the Earth's interior structure, which can move land by centimetres each year.

What causes these devastating natural hazards and what are we doing to predict and prepare for them?

Earthquakes are one of our planet's most destructive natural hazards, with the ability to flatten entire cities, trigger enormous tsunamis that wash away everything in their path, and cause a devastating loss of life.

Part of an earthquake's immense power lies in its unpredictability, as a huge quake can strike with very little warning and give those nearby no time to get to safety. Although we do not know when they will occur, we can predict where they are likely to happen, thanks to our knowledge of plate tectonics.

The thin top layer of the Earth, known as the crust, is divided into several plates that are constantly moving. This is caused by heat from the core of the Earth creating convection currents in the mantle just below the crust, which shifts the plates in different directions.

As the plates move, they collide, split apart or slide past each other along the plate boundaries, creating faults where the majority of earthquakes occur. At divergent or constructive plate boundaries the plates are moving apart, causing normal faults that form rift valleys and ocean ridges. When plates move toward each other along convergent or destructive plate boundaries, they create a reverse or thrust fault, either colliding to form mountains or sliding below the other in a process known as subduction. The third type is a conservative or transform plate boundary, and involves the two parallel plates sliding past each other to create a strike-slip fault.

Being able to identify these fault lines tells us where earthquakes are most likely to occur, giving the nearby towns and cities the opportunity to prepare. Although the secondary effects of an earthquake, such as landslides and fires from burst gas lines, can be fatal, the main cause of death and destruction during earthquakes is usually the collapse of buildings. Therefore, particularly in developed parts of the world, structures near to fault lines are built or

5 TOP FACTS
QUAKE-PROOFING

Animal inspiration
1 Scientists are trying to mimic the threads that mussels use to stay attached to their shells in order to develop construction materials that are rigid but flexible for absorbing shock.

Invisibility cloak
2 Dubbed the 'seismic invisibility cloak', 100 concentric plastic rings would be buried beneath the foundation of a building and deflect the surface waves around the structure.

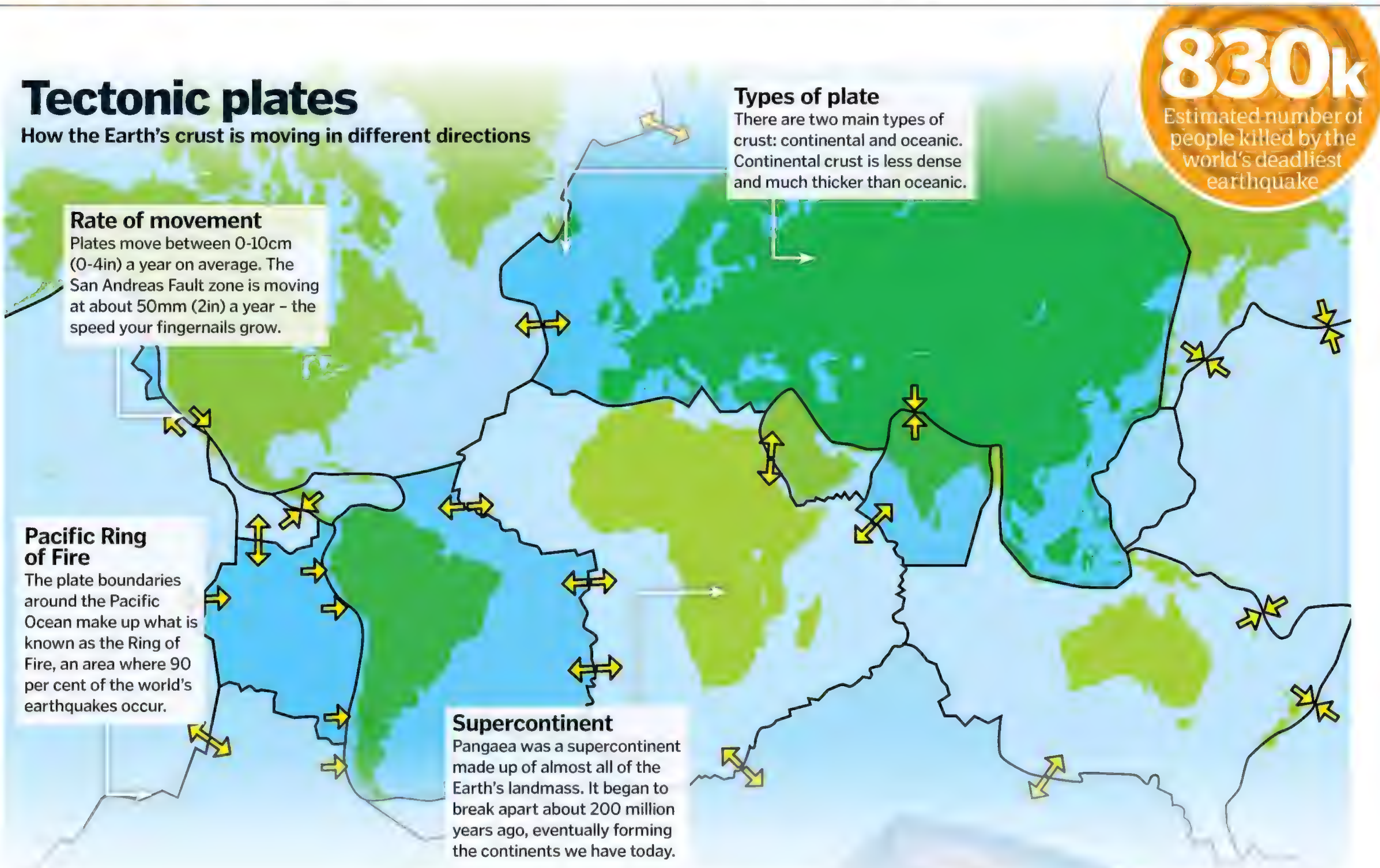
Cardboard constructions
3 Architect Shigeru Ban has designed a church made of 98 giant cardboard tubes reinforced with wooden beams. The cardboard is sturdy but lightweight, so would cause little damage if it collapsed.

Plastic wrap
4 Fiber-reinforced plastic wrap could go around supporting columns in existing buildings. A pressurised adhesive would then be pumped between the column and the wrap.

Smart materials
5 Shape-memory alloys (SMAs) can return to their original shape after experiencing strong forces, so could be used in place of steel and concrete for more resilient buildings.

DID YOU KNOW? *There are ca 500,000 earthquakes in the world each year, but only 100,000 can be felt – 100 of them cause damage*

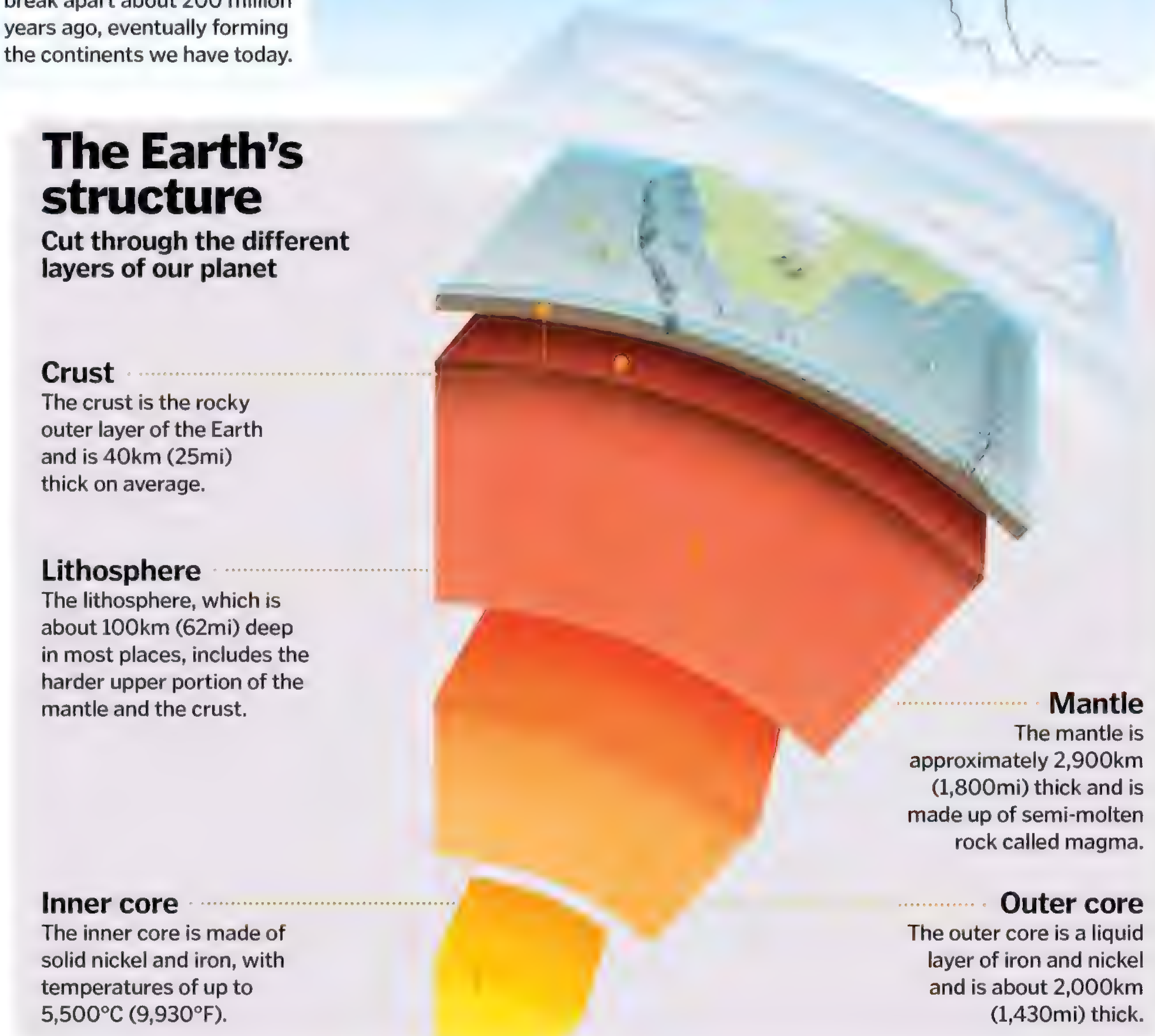
Tectonic plates
How the Earth's crust is moving in different directions



adapted to withstand violent shock waves. The surrounding population will usually carry out regular earthquake drills, such as The Great California ShakeOut, that gives people a chance to practise finding cover when a quake hits. Unfortunately, many poorer areas cannot afford to be so well prepared, and so when an earthquake strikes, the resulting destruction is often even more devastating and the death toll is usually much higher.

However, our knowledge of how earthquakes work and the development of new technologies are helping us to find potential methods for predicting when the next one will strike. Scientists can currently make general guesses about when an earthquake may occur by studying the history of seismic activity in the region and detecting where pressure is building along fault lines, but this only provides very vague results so far. The ultimate goal is to be able to reliably warn people of an imminent earthquake early enough for them to prepare and minimise the loss of life and property. Until then, being under the constant threat of an impending earthquake is unfortunately part of everyday life for those living along the Earth's constantly active fault lines.

The Earth's structure
Cut through the different layers of our planet



Anatomy of an earthquake

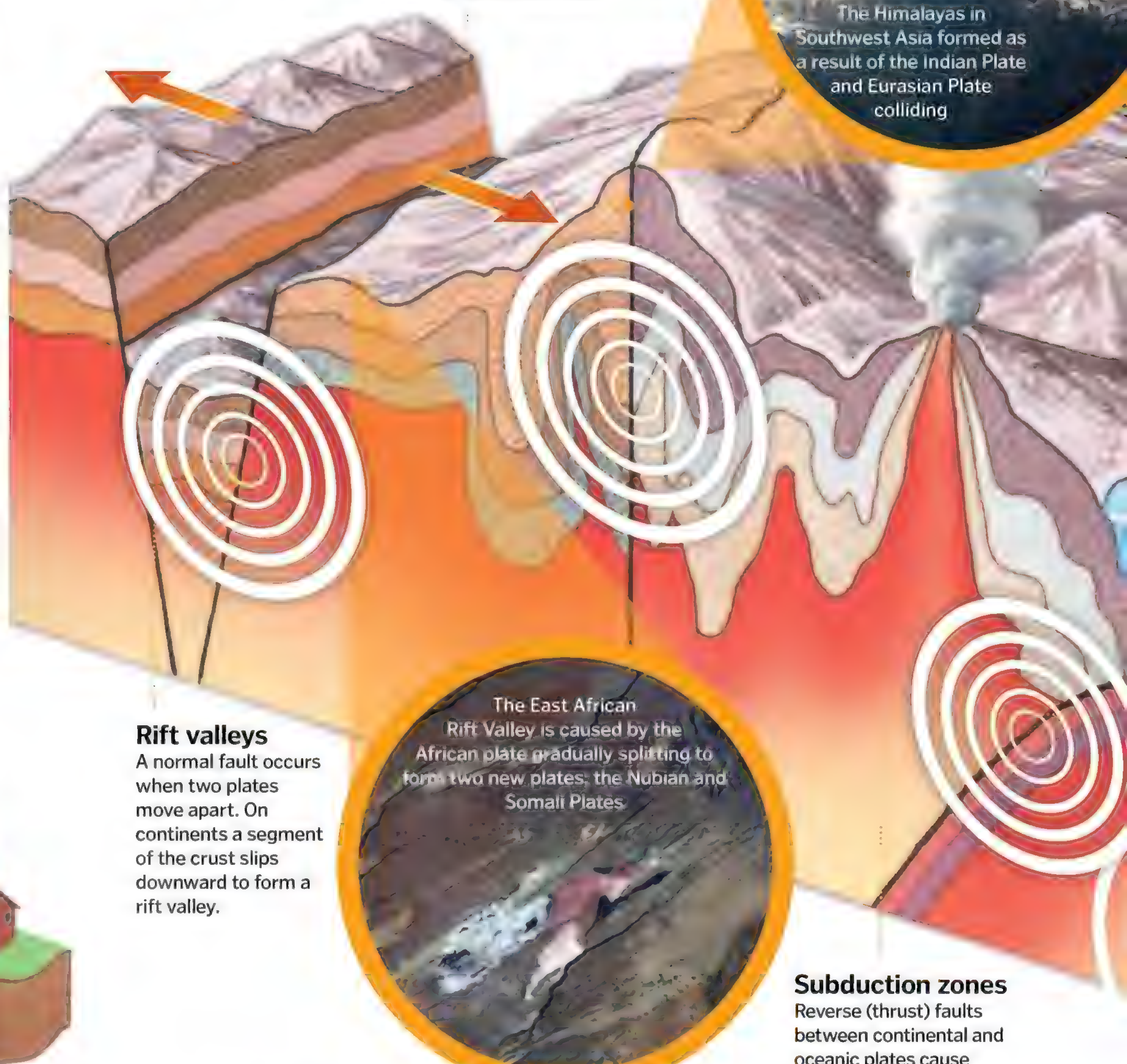
How earthquakes are caused and shake the ground beneath our feet

Earthquakes are caused by the build-up of pressure that is created when tectonic plates collide. Eventually the plates slip past each other and a huge amount of energy is released, sending seismic waves through the ground. The point at which the fracture occurs is often several kilometres underground and is known as the focus or hypocentre. The point directly above it on the surface is the epicentre, and this is where most of the damage is caused. Earthquakes have different characteristics depending on their type of fault line, but when they occur underwater, they can sometimes trigger enormous destructive waves called tsunamis.

Fault lines

How the Earth's crust moves along different plate boundaries

Mountain formation
When two continental plates collide along a reverse (thrust) fault, the Earth's crust folds, pushing slabs of rock upward to form mountains.



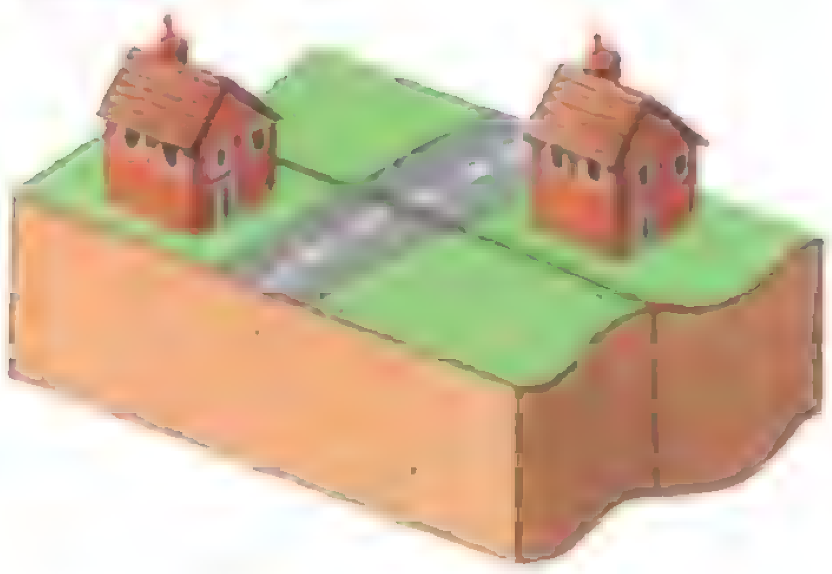
Rift valleys
A normal fault occurs when two plates move apart. On continents a segment of the crust slips downward to form a rift valley.

Subduction zones
Reverse (thrust) faults between continental and oceanic plates cause subduction, causing the higher-density oceanic plate to sink below the continental plate.

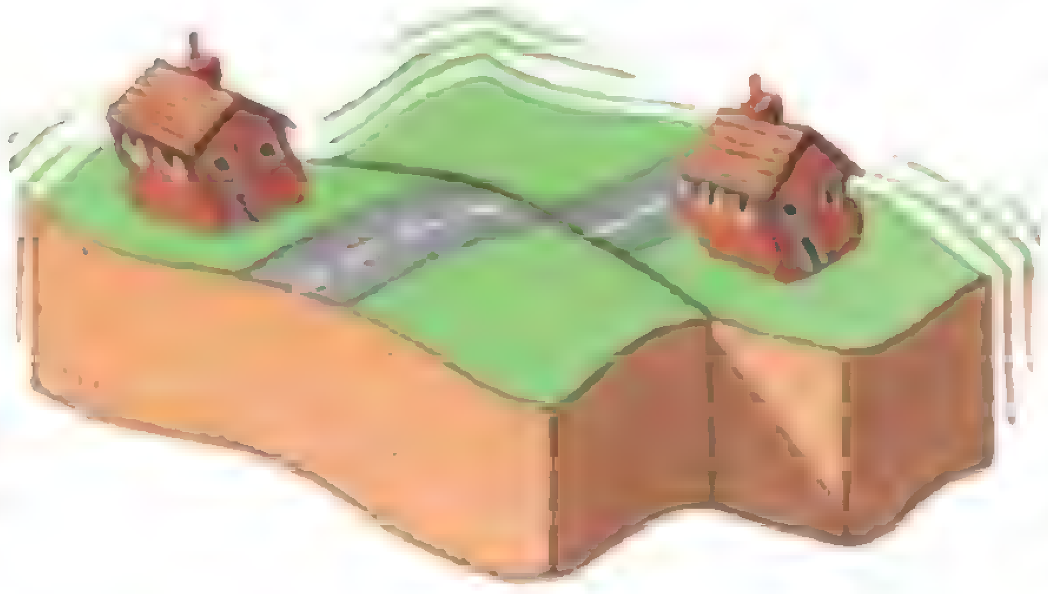
How earthquakes occur

The build-up of pressure that causes the ground to move and shake

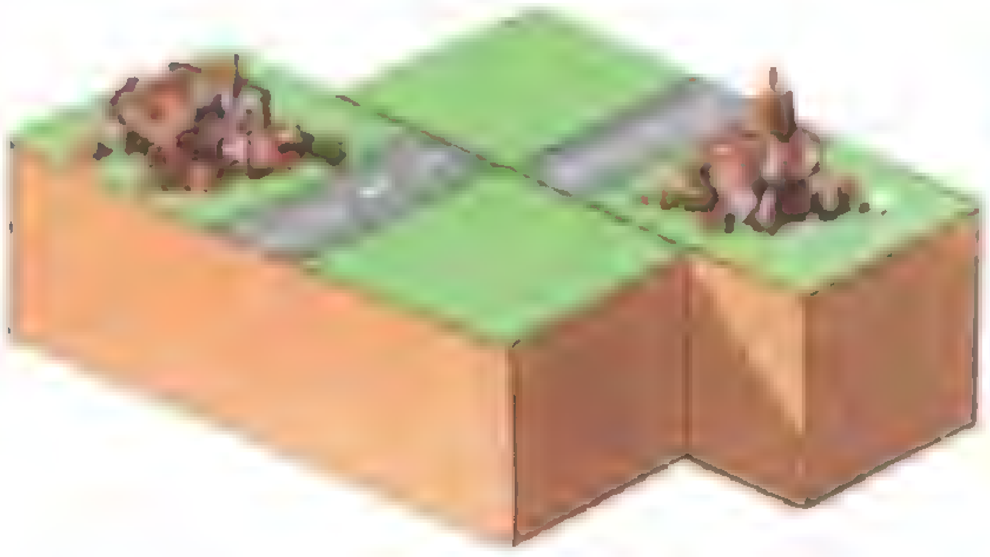
Friction causes pressure
As the tectonic plates are pushed past or into each other, friction prevents them from moving and causes a build-up of immense pressure.



Energy is released
When the pressure finally overcomes the friction, the plates will suddenly fracture and slip past each other, releasing energy and causing seismic waves.



The process starts again
Once the energy has been released, the plates will assume their new position and the process will begin all over again.



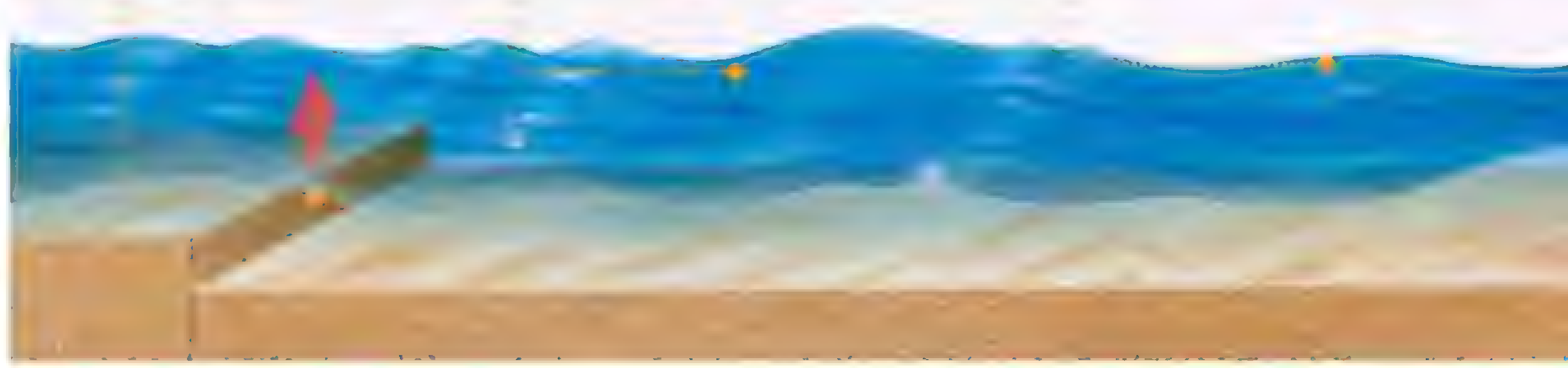
Tsunamis

How underwater earthquakes trigger enormous and devastating waves

Water displacement
As two oceanic plates slip past each other and cause an earthquake, a huge amount of water above it is displaced.

Small beginnings
Small, rolling waves begin to spread outward from the earthquake's epicentre at speeds of up to 805km/h (500mph).

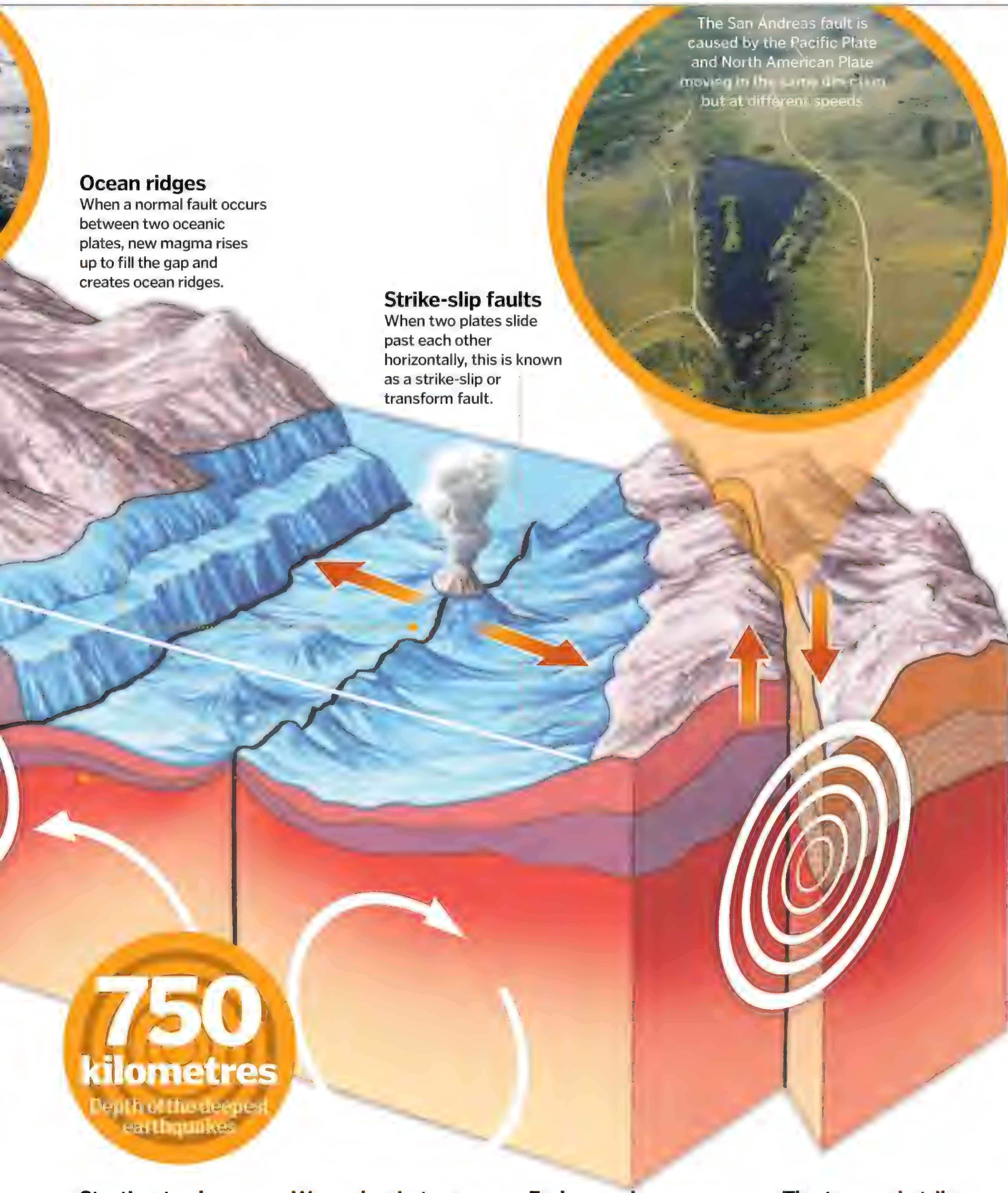
Tsunami in disguise
The tsunami's long wavelength and small wave height – usually less than 1m (3.3ft) – means that it blends in with regular ocean waves.



9.5 MOST POWERFUL EARTHQUAKE

The largest earthquake ever recorded happened on 22 May 1960 in southern Chile. It was caused by the subduction of the Nazca Plate under the South American Plate.

DID YOU KNOW? Tsunamis and tidal waves are different things as the latter is caused by gravitational activity, not earthquakes



The San Andreas fault is caused by the Pacific Plate and North American Plate moving in the same direction but at different speeds

Ocean ridges

When a normal fault occurs between two oceanic plates, new magma rises up to fill the gap and creates ocean ridges.

Strike-slip faults

When two plates slide past each other horizontally, this is known as a strike-slip or transform fault.

750 kilometres
Depth of the deepest earthquakes

Starting to slow

As they reach the shallower waters of the coast, the rising sea floor causes friction that slows the waves down.

Waves begin to grow

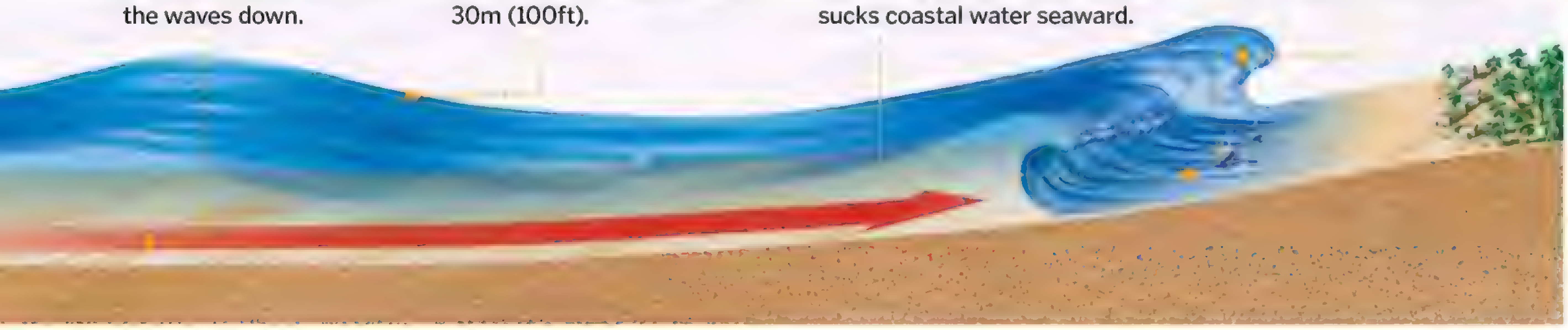
As they slow down, the wavelengths begin to shorten, causing the tsunami to grow to a height of approximately 30m (100ft).

Early warning

A tsunami's trough, the low point beneath the wave's crest, often reaches shore first, producing a vacuum effect that sucks coastal water seaward.

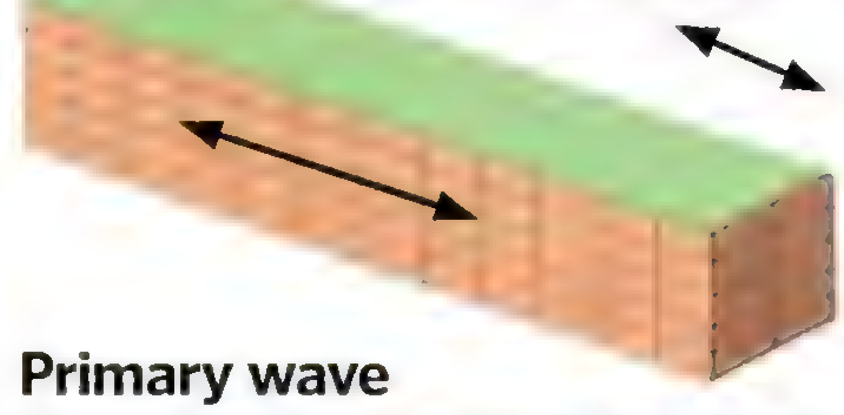
The tsunami strikes

A few minutes later, the tsunami's crest will hit the shore followed by a series of more waves, called a wave train.



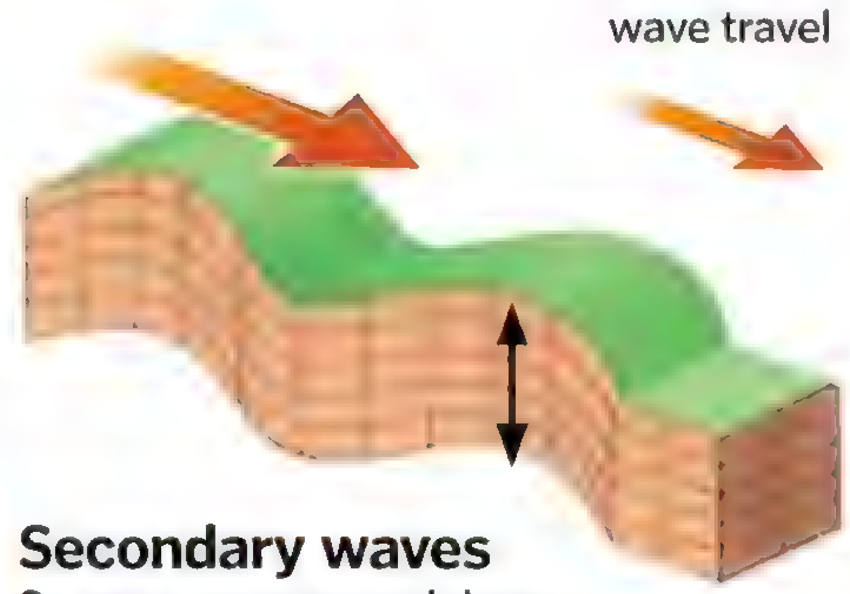
Earthquake waves

How seismic waves travel through the Earth's crust



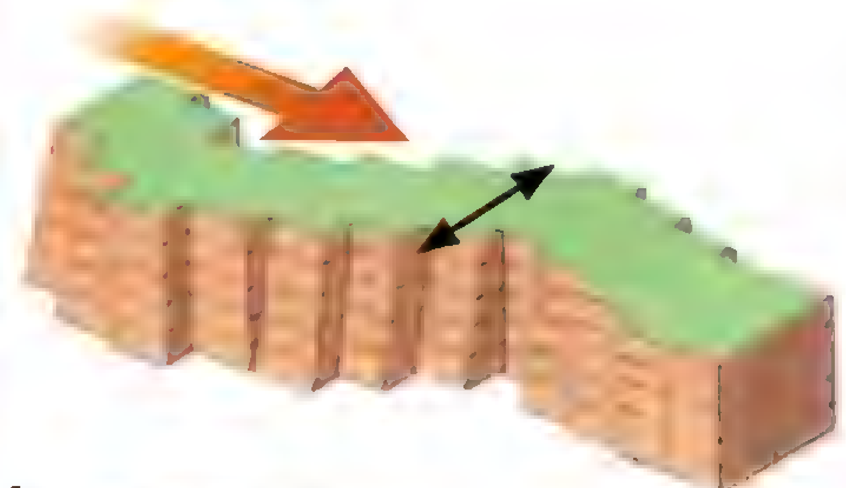
Primary wave

P waves travel back and forth through the Earth's crust, moving the ground in line with the wave. They are the fastest moving of the waves, travelling at about 6-11km/s (3.7-6.8mi/s) , and so typically arrive first with a sudden thud.



Secondary waves

S waves move up and down, perpendicular to the direction of the wave, causing a rolling motion in the Earth's crust. They are slower than P waves, travelling at about 3.4-7.2km/s (2.1-4.5mi/s), and can only move through solid material, not liquid.



Love waves

Unlike P and S waves, surface waves only move along the surface of the Earth and are much slower. Love waves, named after the British seismologist AEH Love, are the faster of the two types and shake the ground side to side, perpendicular to direction of the wave.

Rayleigh waves

Rayleigh waves, named after the British physicist Lord Rayleigh, are surface waves that cause the ground to shake in an elliptical motion. Surface waves arrive last during an earthquake but often cause the most damage to infrastructure due to the intense shaking they cause.

Monitoring earthquakes

Earthquake-recording methods of the past and present

Earthquakes are measured using an instrument called a seismograph, which produces a visual record of tremors in the Earth's crust. This shows the seismic waves of the earthquake as a wiggly line, allowing you to plot the different waves types. The small but fast P waves appear first, followed by the larger but slower S waves and surface waves. The amount of time between the arrival of the P and S waves shows how far away the earthquake was, allowing scientists to work out the exact location of the epicentre. The size of the waves also helps them determine the magnitude or size of the earthquake, which is measured using the Richter Scale.

How a seismograph works

The clever device that records earthquakes as they happen

15 tons

[illegible]

Weight and spring
A heavy weight is hung from a spring or string that absorbs all of the ground movement, causing it to remain stationary.

Pen and paper
The difference in position between the shaking paper and the motionless weight and pen is recorded as wiggly lines.

Base
The base of the seismograph sits on the ground and shakes with the earthquake, also shaking the roll of paper on top.

The earliest known seismograph resembled a wine jar and had a diameter of 1.8m (6ft)

The first seismograph

[illegible]

Modern seismographs send small electric signals to computers and record them on paper

The Richter Scale

Measuring the magnitude of earthquakes using US seismologist Charles F Richter's system

0-2.9
There are more than 1 million micro earthquakes a year but they are not felt by people.

3.0-3.9
Minor earthquakes are felt by many people but cause no damage – there are as many as 100,000 of these a year.

4.0-4.9
Felt by all, light earthquakes occur up to 15,000 times a year and cause minor breakages.

5.0-5.9
A moderate earthquake causes some damage to weak structures. There are around 1,000 of them a year.

Laser beams are used to detect small movements of the ground in Parkfield, California

With a little bit of warning, people can hide under tables and desks to protect them from falling debris in an earthquake

Predicting earthquakes

Modern methods that could help us plot future seismic activity

Currently, earthquakes cannot be predicted far enough in advance to give people much notice, but there are some early warning systems in place to give people a few seconds or minutes to prepare before the serious shaking starts. When seismometers detect the initial P waves, which don't usually cause much damage, they can estimate the epicentre and magnitude of the earthquake and alert the local population before the more destructive S waves arrive. Depending on their distance from the epicentre, people should then have just enough time to take cover, stop transport and shut down industrial systems in order to reduce the number of casualties.

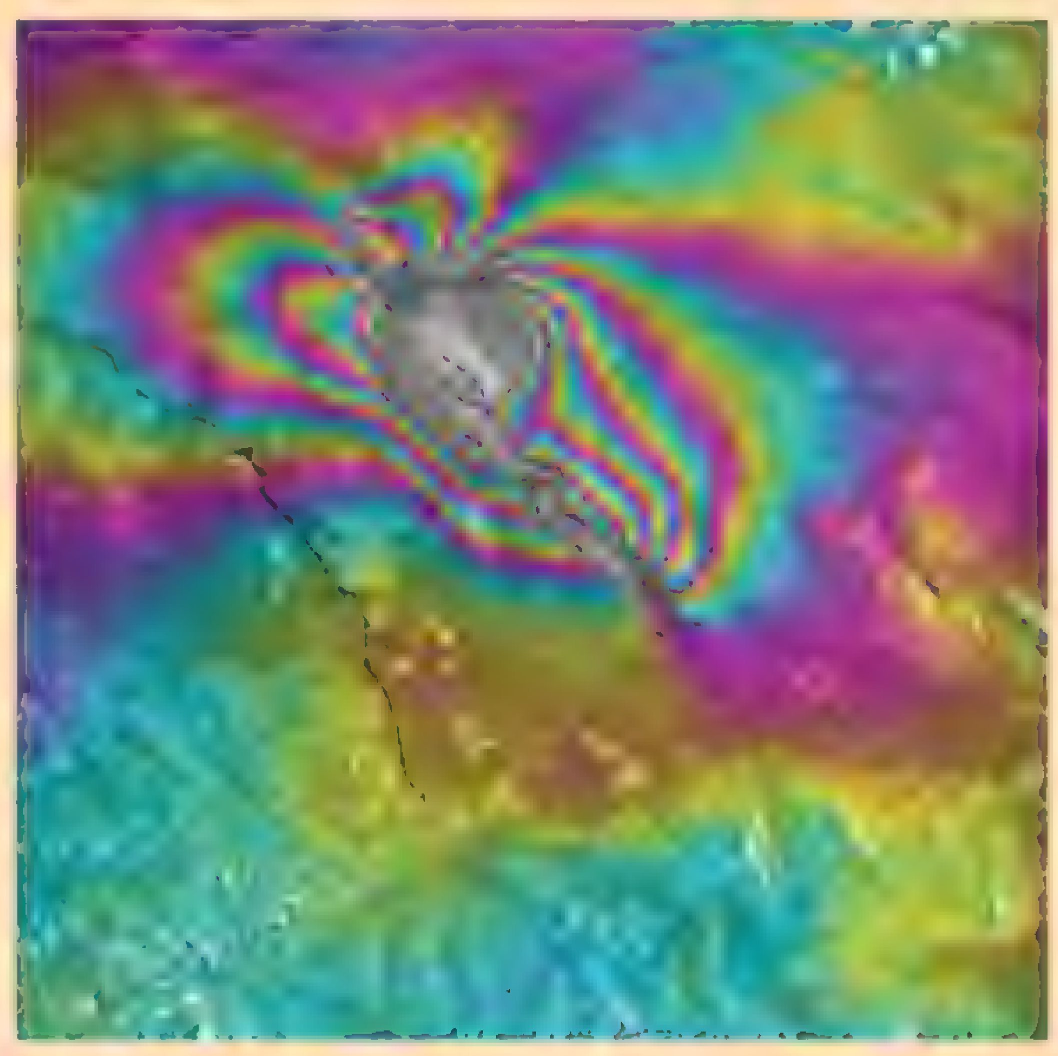
Scientists are also enlisting the help of the general public to help them develop early warning systems. The Quake-Catcher Network (QCN) is a worldwide initiative supplying people with low-cost motion sensors that they can fasten to the floor in their home or workplace. These sensors are then connected to their computer and send real-time data about seismic activity to the QCN's servers, with the hope that earthquake warnings can be issued when strong motions are detected in any of these.

To be able to predict earthquake further in advance, a characteristic pattern or change that precedes each earthquake needs to be identified. One suggestion is that increased levels of radon gas escape from the Earth's crust before a quake, however this can also occur without being followed by seismic activity, so does not provide conclusive evidence of a earthquake.

Scientists are even trying to determine whether animals can predict earthquakes better than we can, but no widespread unusual behaviour has been linked to earthquakes. Other potential earthquake-predicting methods are being tested in Parkfield, California along the San Andreas fault. Among other things, scientists are using lasers to detect the movement of the Earth's crust, sensors to monitor groundwater levels in wells, and a magnetometer to measure changes in the Earth's magnetic field, all with the hope that this will allow them to predict the next big quake.

Radar mapping

One of the more recent developments in earthquake monitoring is interferometric synthetic aperture radar (InSAR). Satellites, or specially adapted planes, send and receive radar waves to gather information about the features of the Earth. The reflected radar signal of a fault line is recorded multiple times to produce radar images, which are then combined to produce a colourful interferogram (below). Each colour shows the amount of ground displacement that has occurred between the capturing of each image, mapping the slow warping of the ground surface that leads to earthquakes. This technique is sensitive enough to detect even tiny ground movements, allowing scientists to monitor fault lines in more detail and detect points where immense pressure is building up. It is hoped that this data will eventually enable scientists to tell when this pressure has reached a hazardous level, leading to more reliable earthquake predictions that give the public days or even weeks to prepare.



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6.0-6.9

Over 100 strong earthquakes happen each year, causing moderate damage in populated areas.

7.0-7.9

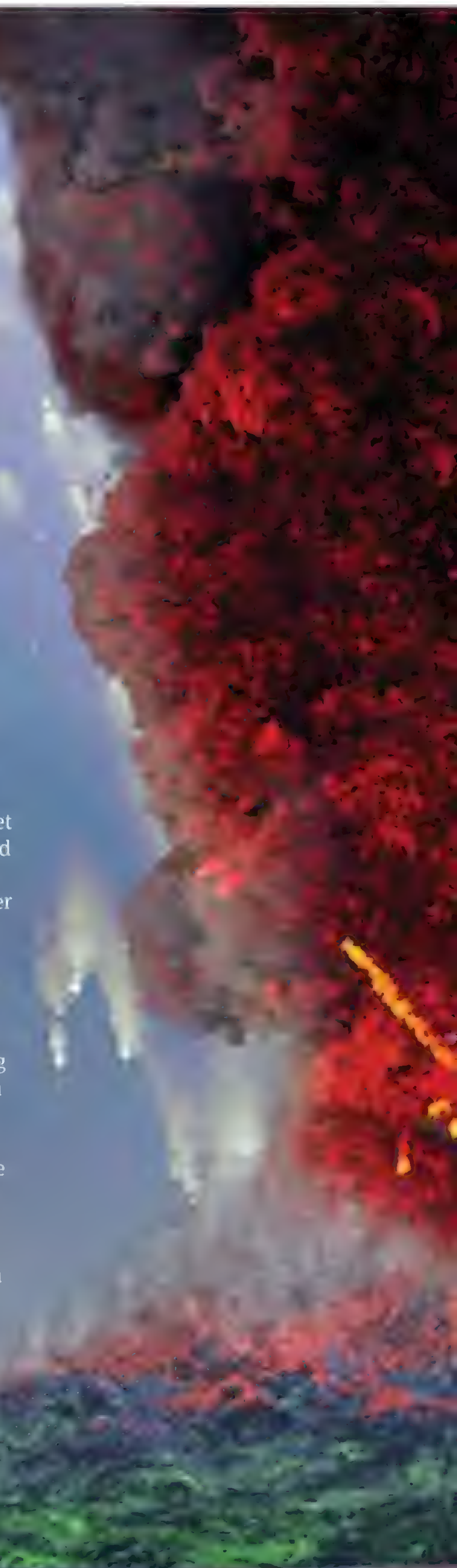
A loss of life and serious damage over large areas are the result of major earthquakes that happen around ten times a year.

8.0 & higher

There are fewer than three earthquakes classed as 'great' each year, but they cause severe destruction and loss of life over large areas.

Volcanoes explained

Around the world, sleeping giants lie in wait for their 15 megatons of fame



Imagine the Earth as a giant ripe orange. Beneath the thin, dimpled peel is a thick layer of pulp and juice, 90 per cent of it liquid. The Earth's peel is called the lithosphere, a fragile crust of rock – 75-150km thick – that floats on a massive sea of impossibly hot, semi-fluid magma that extends 5,000km below the surface.

When German meteorologist Alfred Wegener first proposed his theory of "continental drift" back in 1912, people thought he was crazy. How could a colossal hunk of solid rock such as Asia or Africa possibly drift? As we now know, the continents are indeed solid, but they are fragmented into seven major plates and seven minor plates that eternally jostle for position like buoys on troubled water.

The engines that power this perpetual tectonic dance are giant convection currents in the Earth's molten mantle that slowly push magma upward and outward. Wherever rising magma manages to break through the thin lithosphere, it's called volcanism, but the vast majority of volcanoes aren't the explosive, violent variety. Instead, they are slow-bubbling cauldrons along a 60,000km underwater seam called the mid-ocean ridge.

The mid-ocean ridge is like an open, oozing wound in the crust where two oceanic plates diverge. The plates are pulled away from each other by the slow and steady convection currents and the gap between them is constantly refilled by thousands of unknown, unnamed underwater volcanoes. As this underwater lava cools, it creates new ocean floor covering 60 per cent of the Earth's surface.

Forget the orange analogy and think of the Earth's crust like a giant moving walkway in an airport. The walkway emerges from below the floor, travels a set distance and then rolls back underground. The divergent plate boundaries along the mid-ocean ridge are where the Earth's "moving walkway" begins. The diverging plates are carried along this magma conveyor belt – travelling only three to four centimetres per year – until they meet a plate moving in the other direction.

When two plates converge, something has to give. An incredible 90 per cent of earthquakes occur along convergent plate boundaries and so do the world's biggest and deadliest volcanoes. The prime example is the Ring of Fire, the unbroken string of seismic and volcanic activity that encircles the Pacific Ocean. The Ring of Fire is a giant subduction zone, where oceanic plates "dive" below continental plates and are melted back into magma in the blazing hot forge of the mantle.

Ocean sediment holds tons of water, carbon dioxide, sodium and potassium. When oceanic crust enters the blast furnace of the mantle, these sea-borne elements lower the melting point of surrounding rock, forming a gaseous, yet viscous magma that rises quickly toward the surface. If the rising magma reaches an obstacle – an impenetrable thick layer of solid rock – it pools below the surface, building increased pressure as more gaseous, volatile molten materials push up from below.

And then one day – boom! All it takes is a weak point in the cap of rock holding back the magma. On Mount St. Helens, a landslide cleared a swath of rock from the north flank of the mountain, lowering the downward pressure on the boiling pot of magma below. The result was an explosion that produced a monstrous pyroclastic surge – a wall of searing hot fluidised gas, debris and ash – that vaporised everything within a 500-square-kilometre area.

Some of the most famous and infamous eruptions came from subduction zone volcanoes ►

"90 per cent of earthquakes occur along convergent plate boundaries and so do the world's biggest and deadliest volcanoes"

How many active?
1 There is some disagreement on what makes a volcano "active" but 1,510 volcanoes have erupted in the last 10,000 years. There are many more volcanoes on the sea bed.

Biggest in the world?
2 The biggest volcano in the world is Mauna Loa in Hawaii. Its whole volume is about 80,000 cubic kilometres. Its most recent eruption occurred on 24 March 1984.

Can they do good?
3 Volcanic slopes left after an eruption are very steep, so rare and delicate plants and animals can set up home there and be protected. Volcanic ash is very good for soil.

Eyjafjallajökull
4 The Icelandic volcano that caused so much disruption to European flights, the crater of the volcano measures 1.8 miles to 2.5 miles across (three to four kilometres).

Largest in the solar system
5 In the wider solar system, Mars is believed to hold the honour of housing the largest volcano – the 17-mile tall Olympus Mons. More on this next issue.

DID YOU KNOW? The loudest noise in history was the eruption of Krakatoa in 1883, a 180dB explosion heard 3,500km away

Why volcanic eruptions can spark lightning

The mesmerising lightning storms that danced among the ash clouds of Iceland's Eyjafjallajökull volcano were caused by the same conditions that trigger regular thunderstorms. High in the black clouds of a rainstorm, hail and water droplets whirl and collide, freeing large amounts of electrons. Newly charged positive ions congregate in the upper portion of the clouds while the negative particles drift downward. When the charge separation becomes too great, a spark of lightning releases the pent-up energy, bringing the system back to equilibrium.

In a volcanic lightning storm, the same principles are at work. In this case, the colliding particles include ash, water and even hail. Electrical fields form within the ash cloud and the frequent and eye-popping lightning strikes (often in vivid purple and orange colours) resolve the charge separations. Another ingredient of volcanic lightning is electrically charged silica particles that are blown airborne from deep in the earth.

along the Ring of Fire: Tambora in Indonesia, Pinatubo in the Phillipines, Gagxanul in Guatemala, Mount Pelée in Martinique, the list of killer volcanoes goes on. In fact, 400 of the world's 500 known active volcanoes occur along subduction boundaries.

But not all famous volcanoes are of the subduction variety. The volcanoes of the Hawaiian Islands are an example of something called hot spot volcanism. Think back to those powerful convection currents in the mantle that push magma upward toward the crust. In certain 'hot spots' around the entire planet, convection currents are able to ooze magma to the surface with very little resistance.

Picture the hot spot under the Hawaiian Islands as a giant tube of toothpaste. Squeeze the tube and the little dollop of paste becomes the first Hawaiian Island, Kauai. Now keep the tube in the same place while the ocean plate travels a few hundred kilometres northwest. Squeeze the tube again and you've created the second island, Oahu. Hawaii, the Big Island, is still sitting over that magma pump, fuelling magnificent, slow-boiling eruptions that are literally building the island.

The intensity and duration of a volcanic eruption depends mostly on the consistency of the magma rising to the surface and the obstacles preventing the magma from reaching the surface. Subduction volcanoes are so ear-poppingly explosive because the magma fuelling them is loaded with gas bubbles and silica from sea floor sediments. The high silica content makes the magma more viscous, preventing gas bubbles from easily escaping. The result is like shaking a bottle of soda. When that pressure is released – pop!

Egmont
The Space Shuttle Atlantis exposed this image of the Mount Egmont volcano, New Zealand.

Young!
Egmont is a young stratovolcano that began to form 70,000 years ago.

The hot spot volcanoes of Hawaii, on the other hand, feature highly fluid magma formed from basaltic rock with low silica content. The 'watery' quality of Hawaiian magma allows gas to escape easily. After an initial, relatively calm eruption, Hawaiian volcanoes spew fountains of lava forming large river-like flows that creep slowly to the sea.

The Hawaiian volcanoes Mauna Loa, Kilauea and Mauna Kea are the most closely studied volcanoes in the world, which is why different varieties of lava are classified with Hawaiian names. Pahoehoe is a highly fluid basaltic lava that cools with a smooth, ropy surface. A'a is a thicker lava carrying large chunks of pyroclastic debris like lava blocks and bombs. The result is a slow, jagged flow that cools with a very rough-looking texture.


Lava flow crossing a road during volcanic activity on Reunion, an island in the Indian Ocean

Types of volcanic eruption

Oozing, bubbling, spraying, fountaining, splattering, exploding! When magma reaches the surface, it's sure to be a memorable event. Check out the many different kinds of volcanic eruptions.

Eruption type: Magmatic

Strombolian
Huge gas bubbles rise and explode at the surface, shooting fast-cooling projectiles like lava bombs, glassy spatter and ash.

Vulcanian
Caused by the sudden release of a lava plug, these violent bursts of lava can send molten material several kilometres in the air.

Pelean
Incredibly deadly, a towering wall of rock, debris and lava pour down the slope of a volcano at speeds upwards of 150km/h.

Hawaiian
The classic Kilauea-style eruption is where highly fluid lava 'fountains' spurt upward from long, narrow fissures or vents.

INSTANT KILLER

1. Mount Pelée

On 8 May 1902, a pyroclastic flow travelling at a rate of 160km/h incinerated the town of Saint-Pierre, Martinique, killing all but two of its 28,000 residents.

WORLD CHANGER

2. Tambora

The largest eruption in recorded history, this Indonesian volcano's 1815 eruption took at least 71,000 lives, approximately 11,000 of those directly from the eruption.

SUPERVOLCANO

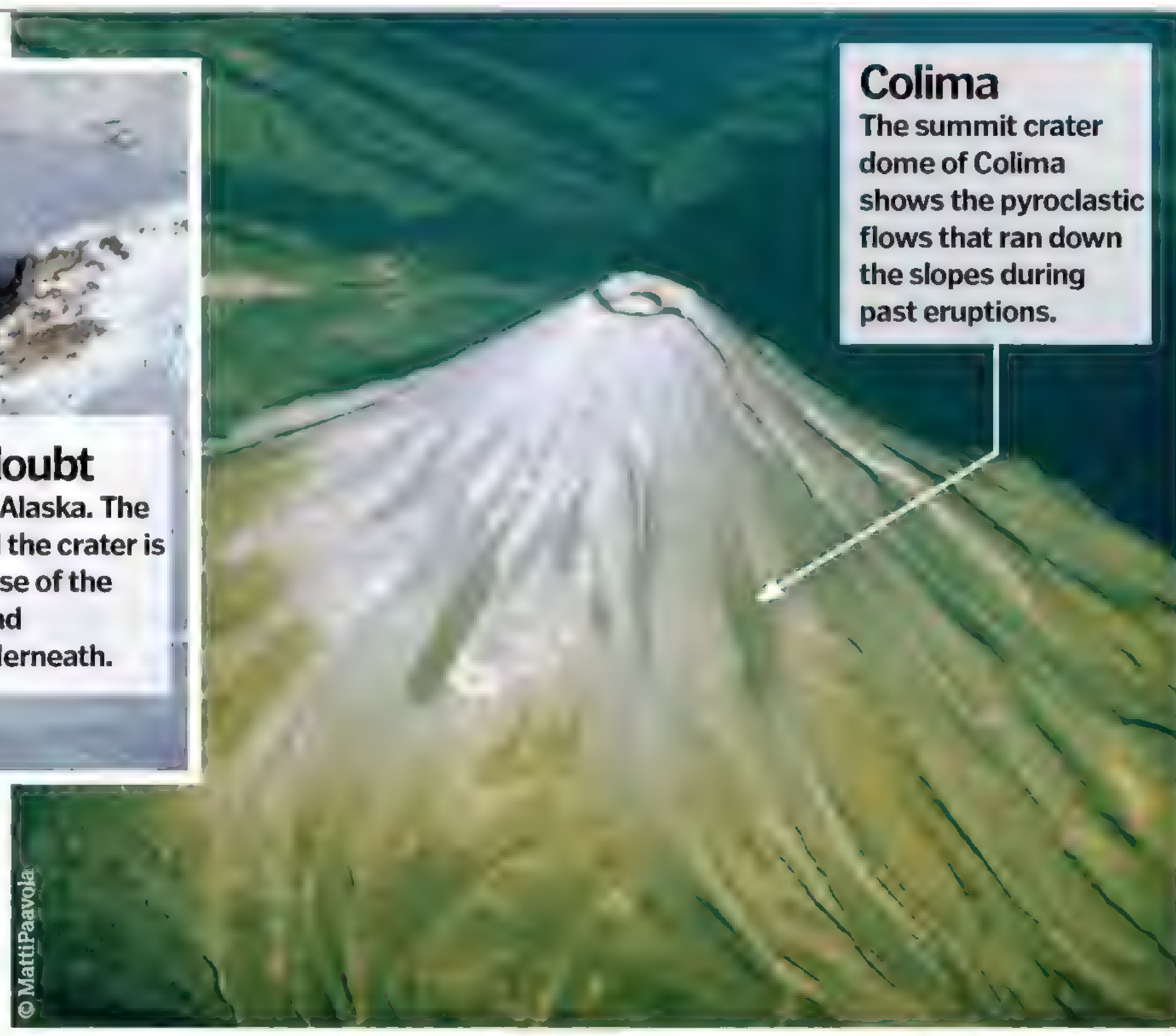
3. Yellowstone caldera

Over 500,000 years ago, an eruption 1,000 times as powerful as Mt St Helens blew the lid off of the western US, creating the Yellowstone caldera.

DID YOU KNOW? *The ash from the 1815 eruption of Tambora created a "year without summer" as far away as New York*

Mount Redoubt

Mount Redoubt, Alaska. The glacier that filled the crater is collapsing because of the increase in ground temperature underneath.



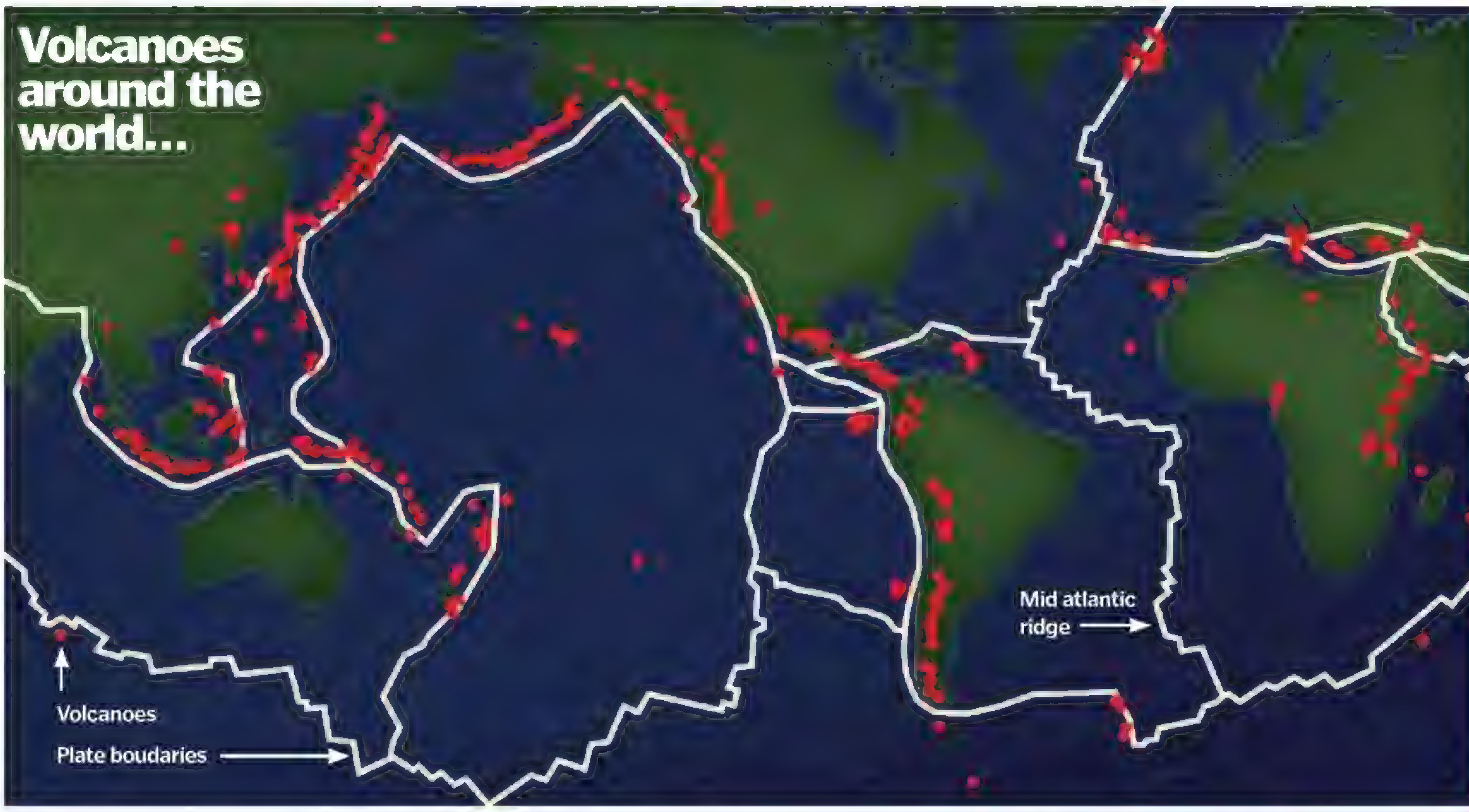
Colima

The summit crater dome of Colima shows the pyroclastic flows that ran down the slopes during past eruptions.

A colourful stromboli eruption

When a lava flow meets water, you get some lovely rounded formations called pillow lava, but if freshly emerging magma meets water, the results are far more explosive. A phreatic or 'steam blast' eruption discharges large rock fragments and ash, but little lava. The monstrous ash cloud that grounded flights across Europe for weeks was the product of magma meeting glacial ice. The ash from such an eruption isn't the soft, fluffy stuff that gets in your eyes when you have a campfire. Volcanic ash particles are hard, jagged fragments of rock, minerals and glass that can be up to 2mm in diameter.

The effect of a large-scale volcanic eruption is both local and global, immediate and long-term. Pyroclastic surges travelling 150km/h can obliterate an entire city in a matter of seconds, while a massive ash storm can block the Sun's rays so thoroughly that the Earth's surface temperature lowers for months, if not years. The 1815 eruption of Tambora in Indonesia spewed so much ash into the global atmosphere that it created a "year without a summer", complete with June snow storms in New York.



Surtseyan
When a boiling underwater volcano breaks the ocean surface, the result is an explosive hydromagmatic reaction.

Submarine
Over 75 per cent of the magma that reaches the surface originates along the mid-ocean ridges that circle the planet.

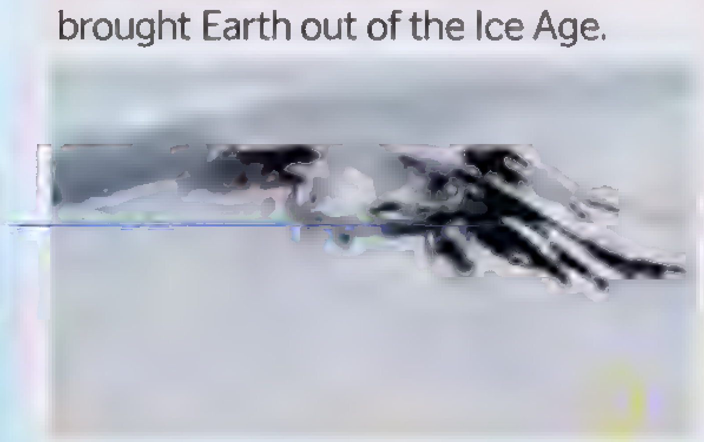
Subglacial
When magma surfaces underneath a sheet of glacial ice, the combination can trigger a lahar, a mud and debris flow.

Phreatic
When emerging magma meets a body of water, the superheated water instantly vaporises, creating a monumental 'steam blast'.

Learn more

In the Discovery Channel's online video archives, you can watch 20 informative video clips from TV documentaries such as *Ultimate Guide To Volcanoes*, including rare footage of a pyroclastic flow **http://dsc.discovery.com/videos/volcano-video**.

For a video featuring our old friend Professor Iain Stewart (interviewed back in issue 6), check out **HIWTV** for a clip from NatGeo, which reveals how volcanoes brought Earth out of the Ice Age.



"In the year-round warm and wet conditions, plants can grow, flower and fruit nonstop"

Multistorey life in the rainforest

The rainforest is a three-dimensional world, with multiple levels of wildlife up its towering trees

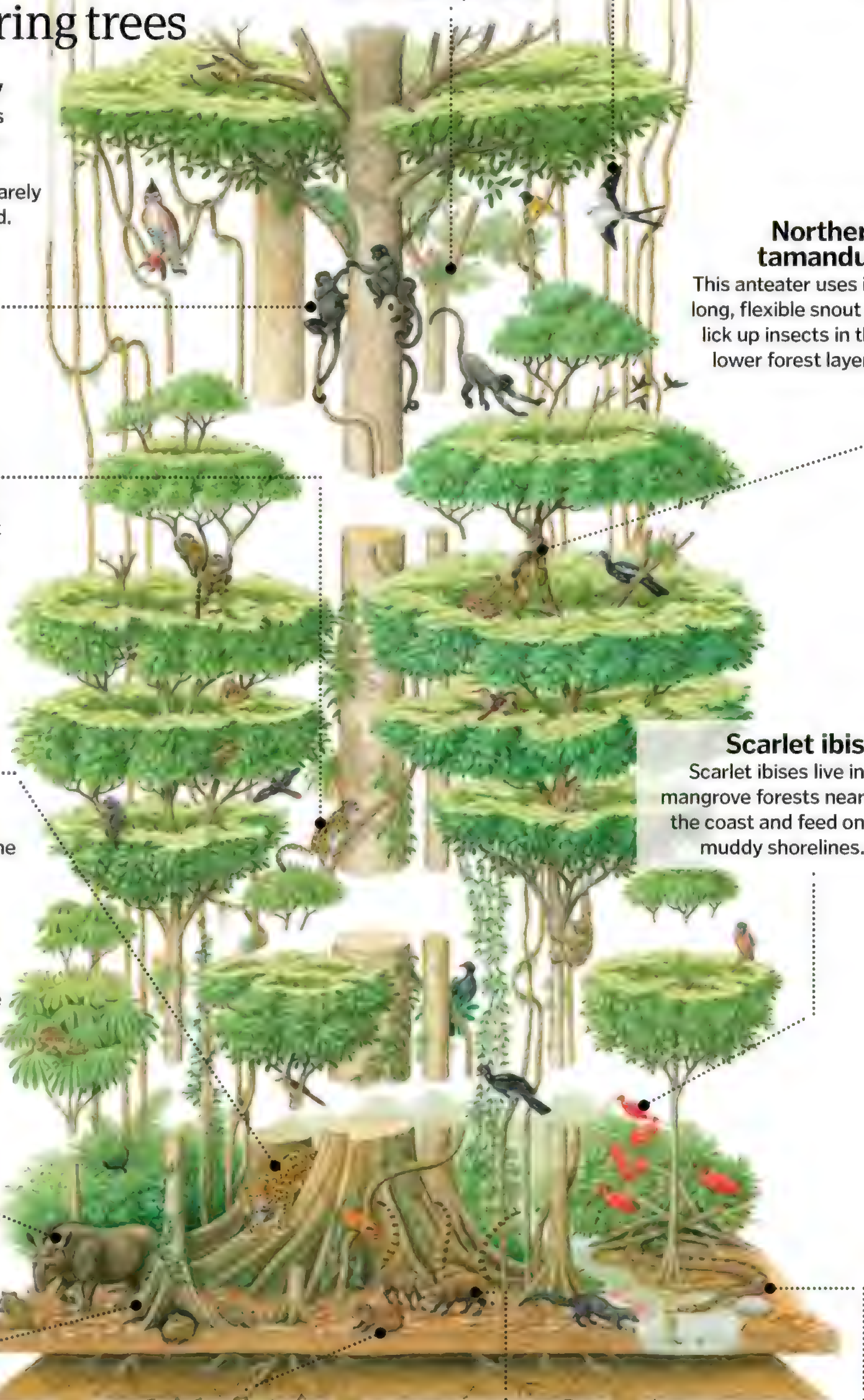
Tropical rainforests are incredibly rich in wildlife. They cover about two per cent of Earth's surface, yet they are home to around half of all the known species of flora and fauna. In the year-round warm and wet conditions, plants can grow, flower and fruit nonstop. That allows trees to quickly reach great heights. In a typical rainforest, the treetops overlap to form a continuous green layer called the canopy, about 45 metres (150 feet) above ground level. A few trees, called emergents, project well above this canopy – the tallest reaching over 80 metres (260 feet) high.

The dense canopy of leaves blocks most sunlight from reaching the ground, where it is shady, damp and dank. For a visitor expecting to see a jungle full of colourful birds and monkeys, the rainforest floor is disappointing. A few small mammals do scurry about here, feeding on fruit that's dropped from above, but they are mostly shy and secretive. Wild cats, like ocelots and jaguars, hunt them – mainly at night – but these are even more difficult to spot.

Life on the forest floor is mostly small and hidden. Dead animals, broken branches and even whole trees from above are the food for myriad insects, worms and fungi. Along with bacteria, these decomposers play a vital role, quickly breaking down the detritus and releasing minerals and nutrients back into the soil to nourish new life in a perpetual cycle.

Meet the low life

The lower storeys of the rainforest are leafy and shady, but jam-packed with hidden life



Epiphytic orchid
9,000 species of orchid live as epiphytes – growing on the platform of a branch, but extracting nothing from the tree like a parasite.

Swallow-tail kite
This agile bird of prey soars above the canopy, searching for reptiles sunning on branches, then swoops in to snatch them.

Woolly monkey
These noisy monkeys travel by day in large troops through the middle canopy, and rarely venture to the ground.

Northern tamandua
This anteater uses its long, flexible snout to lick up insects in the lower forest layers.

Ocelot
Ocelots are medium-sized cats. They hunt mainly on the forest floor, and spend the day well-hidden asleep in trees.

Scarlet ibis
Scarlet ibises live in mangrove forests near the coast and feed on muddy shorelines.

Jaguar
Jaguars are shy, solitary and rarely seen. They hunt on the rainforest floor, and climb trees only to escape danger.

Brazilian tapir
Tapirs are only active at night, foraging in swampy terrain. They hide in dense undergrowth by day.

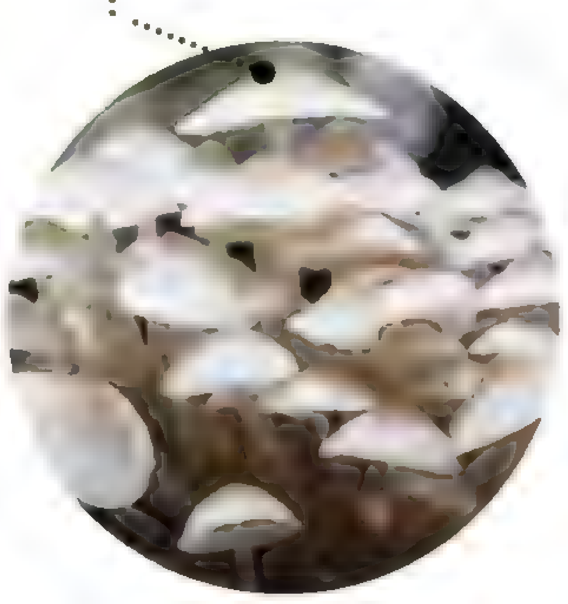
Buttress root
Tree roots get little grip in thin rainforest soils, so many trees also have massive buttress roots to help prop them up.

Paca
A species of agouti (a rodent), the paca has strong enough jaws to open brazil nut fruit and release their seeds.

Coati
Coatis move in groups across the forest floor. They climb to mid-level in the trees, using their tails for balance.

Anaconda
This huge snake lives near rivers and swamps, hunting reptiles and small mammals, which it coils around to kill.

Poison-arrow frog
Bright colours warn predators that these amphibians are deadly. Native Indians use the poison to tip their arrows.



Rainforest fungi
Rainforest fungi produce a spreading network of fine threads to decompose dead wood. These 'mushrooms' are their spore-producing fruiting bodies.

Common anaconda
This snake often reaches ten metres (33 feet) long. The reticulated python can be equally long, but the anaconda is bulkier.

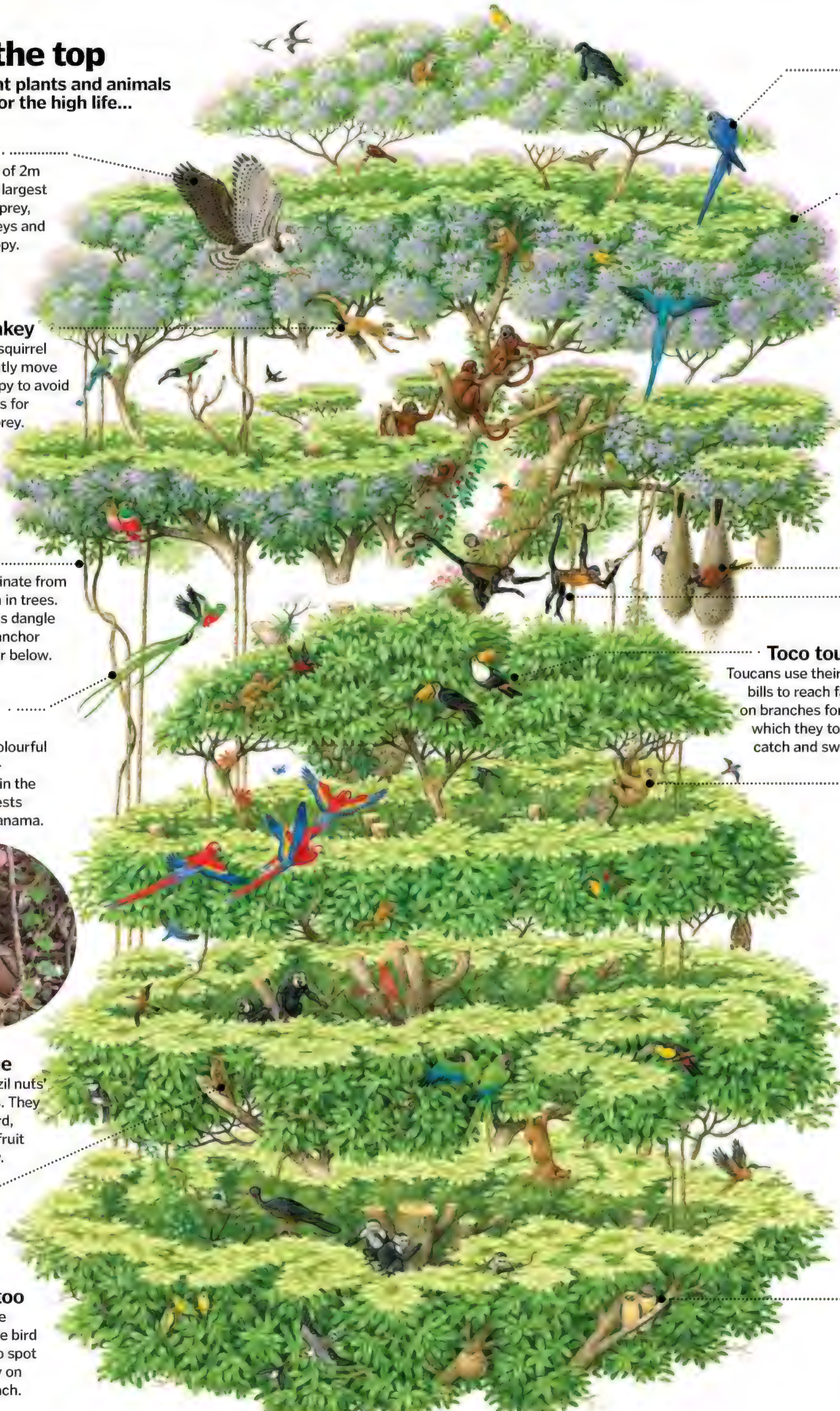
Amazonian rainforest trees
A recent study showed that many trees in the Amazon are over 300 years old. Some even reach grand ages of 750-1,000 years.

African elephant
Elephants in central Africa sometimes move from the open savannah into dense rainforests. They can weigh up to ten tons.

DID YOU KNOW? A football pitch-sized area of rainforest can hold 480 species of tree; a European forest might have just six

Life at the top

Many different plants and animals are adapted for the high life…



Harpy eagle
With a wing span of 2m (6.6ft), this is the largest rainforest bird of prey, feeding on monkeys and sloths in the canopy.

Squirrel monkey
Family groups of squirrel monkeys constantly move through the canopy to avoid being easy targets for passing birds of prey.

Liana
These vines germinate from seeds lodged high in trees. Their feeding roots dangle down in order to anchor them in the soil far below.

Resplendent quetzal
The quetzal is a colourful bird with long tail-streamers, found in the canopy of rainforests from Mexico to Panama.

Brazil nut tree
What we call 'brazil nuts' are actually seeds. They develop inside hard, cannonball-sized fruit in the mid-canopy.

Common potoo
Clever camouflage makes this owl-like bird near-impossible to spot as it sleeps by day on top of a dead branch.

Blue-and-yellow macaw
These large members of the parrot family fly in flocks of up to 20, searching the canopy for ripe fruit.

Flowering tree
In tropical rainforests, some trees flower and others produce fruit all year, ensuring plentiful food for the many animals.

Crested oropendola
The pouch-like nests of these birds are a distinctive feature, dangling in groups from the ends of branches near rivers.

Spider monkey
Spider monkeys sometimes hang on their prehensile tails as they forage for fruit and nuts high in the canopy.

Toco toucan
Toucans use their large bills to reach far out on branches for fruit, which they toss up, catch and swallow.

Three-toed sloth
Algae growing on the fur of slow-moving sloths give them a greenish colour which helps camouflage them amid the foliage.

Epiphytic bromeliad
Epiphytes, like this bromeliad, are sometimes called air plants because they grow in 'mid-air', with no connection to the soil.

Spectacled owl
These birds hunt at night among forest trees. They communicate with calls that sound like someone shaking metal sheeting.

"Camp IV is the point of no return for climbers attempting to reach the summit"

Mount Everest

How do climbers tackle the world's highest mountain?

There are two main routes used by climbers to reach the summit of Everest, the North Ridge Route – which begins in Tibet and is a technically harder climb – and the South Ridge Route, which starts in Namche Bazaar, Nepal, and is the easier and more popular way up top. Within these two routes there are roughly 15 different ways to reach the summit of the mountain, a choice that rests on the experience and number of people ascending.

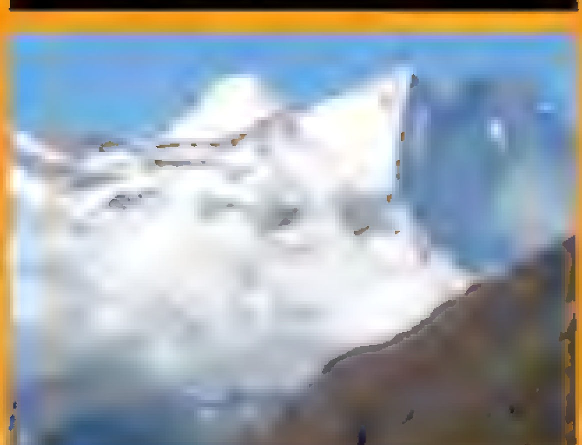
The South Ridge Route, which is the focus of this guide, is split into five camps (including Base Camp) and takes on average four days for its climbers to reach the summit. This route technically begins at Base Camp (5,380m), a six to eight day hike from Kathmandu that allows climbers to acclimatise to the higher altitudes. Once acclimatised at Base Camp, climbers are then forced to cross the Khumbu Icefall, a treacherous series of ice sheets, crevasses and shifting blocks that have claimed the lives of many Sherpas and mountaineers. With the help of fixed ropes and metal ladders however, climbers can then progress up the Icefall to Camp I (6,065m).

From Camp I climbers then continue up the Western Cwm (Cwm is pronounced 'coom'), a relatively flat, gently sloping glacial valley nicknamed the 'Valley of Silence' due to its lack of wind, to the bottom of the Lhotse face where Camp II (6,500m) is situated. From there, climbers must then ascend the Lhotse face by a series of fixed ropes up to Camp III (7,470m), which itself is positioned on a small, narrow shelf of rock, snow and ice. 500 metres on from Camp III lies the last of the five camps on Everest's South Col (Camp IV – 7,920m) and at the start of the Death Zone, the point where the levels of oxygen cannot sustain human life over extended periods of time.

Camp IV is the point of no return for climbers attempting to reach the summit, and for many, this is the point where a summit ascent ends, as if the weather does not suit it is impossible to continue. Providing all is well however, climbers then make

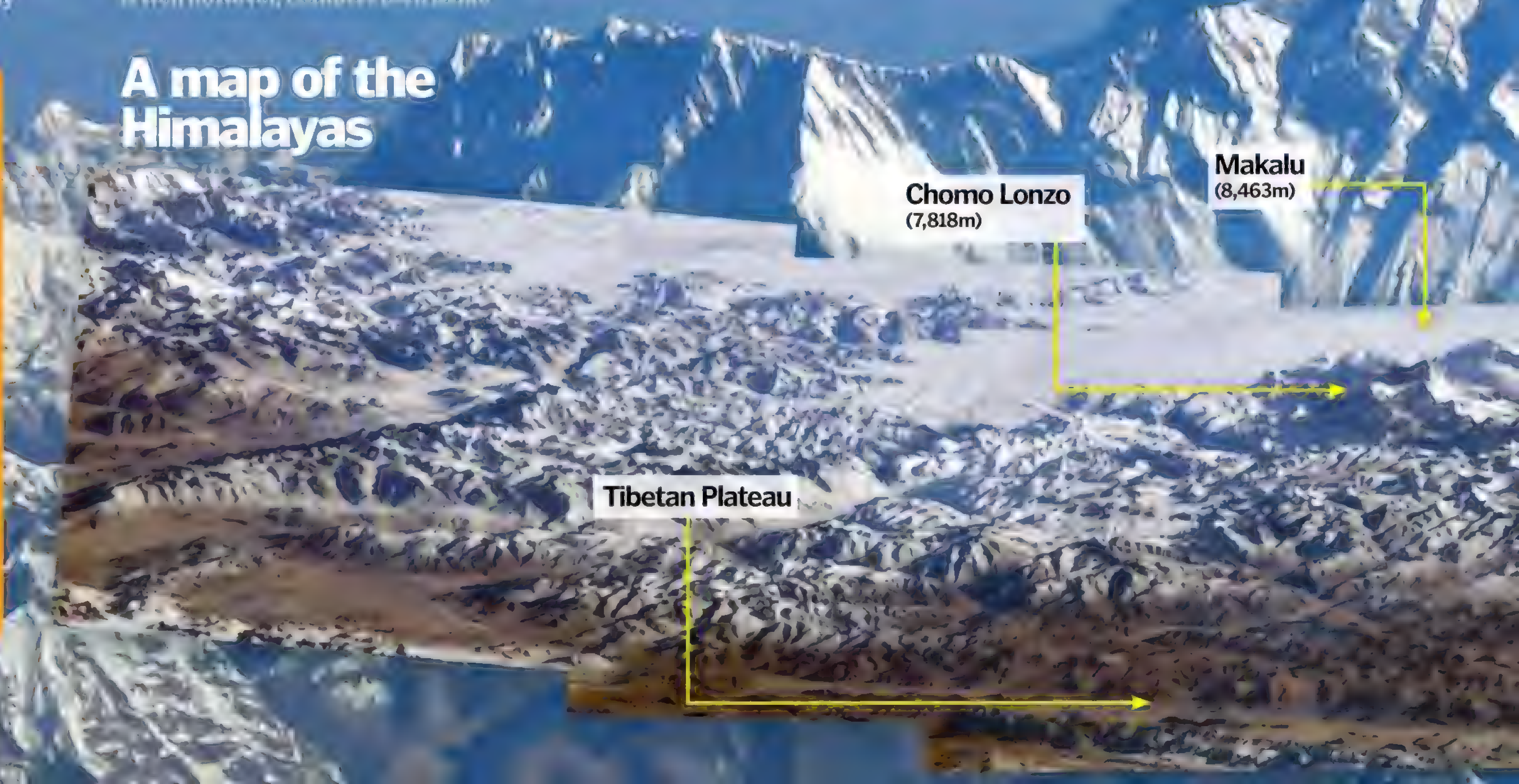
The Statistics

Mount Everest



Name: English – Everest
Tibetan – Chomolungma
Height: 8,848m (29,029ft)
Deaths: 216
Routes to summit: 15
Camps: 5
Climbing cost: $25,000 (average permit)
Climbing season: May, September and October

A map of the Himalayas



5 TOP FACTS EVEREST

Colonial

1 Mount Everest was named after the Surveyor General of India, George Everest, in 1865. Interestingly, Everest himself actually disapproved of the name.

Partnership

2 The first successful accent of Mount Everest was completed back in 1953 by New Zealander Edmund Hillary and Tenzing Norgay, a Nepalese Sherpa.

Close shave

3 The very first aircraft to fly over the peak of Mount Everest was an RAF Westland PV3 in 1933. Its crew recorded that they only just scraped over the summit.

Death toll

4 Out of the 216 people who have died on Everest, 150 of their corpses have never been recovered, with bodies purposely left due to safety considerations.

King of kings

5 Everest beats its closest competitor, Pakistan's K2, in raw height by 227 metres. This fact comes despite K2 being the harder climb out of the pair.

DID YOU KNOW? There are only 14 mountains on Earth that are over 8,000 metres in height above sea level

their final and most dangerous push to the summit, a task which must begin between 12 and 1am in order for the ascent and descent to be made in a single day. Between the camp and the peak lies two imposing obstacles, the 'Cornice traverse' – a knife-edge horizontal ridge with the 2,400m southwest face on one side and the 3,050m Kangshung face on the other – and then, at the end of the traverse, the daunting 'Hillary Step' 12-metre high rock wall. Again through a series of fixed ropes, climbers must ascend this to reach the gentler – albeit heavily exposed – slopes that wind their way to the summit (8,848m). ●

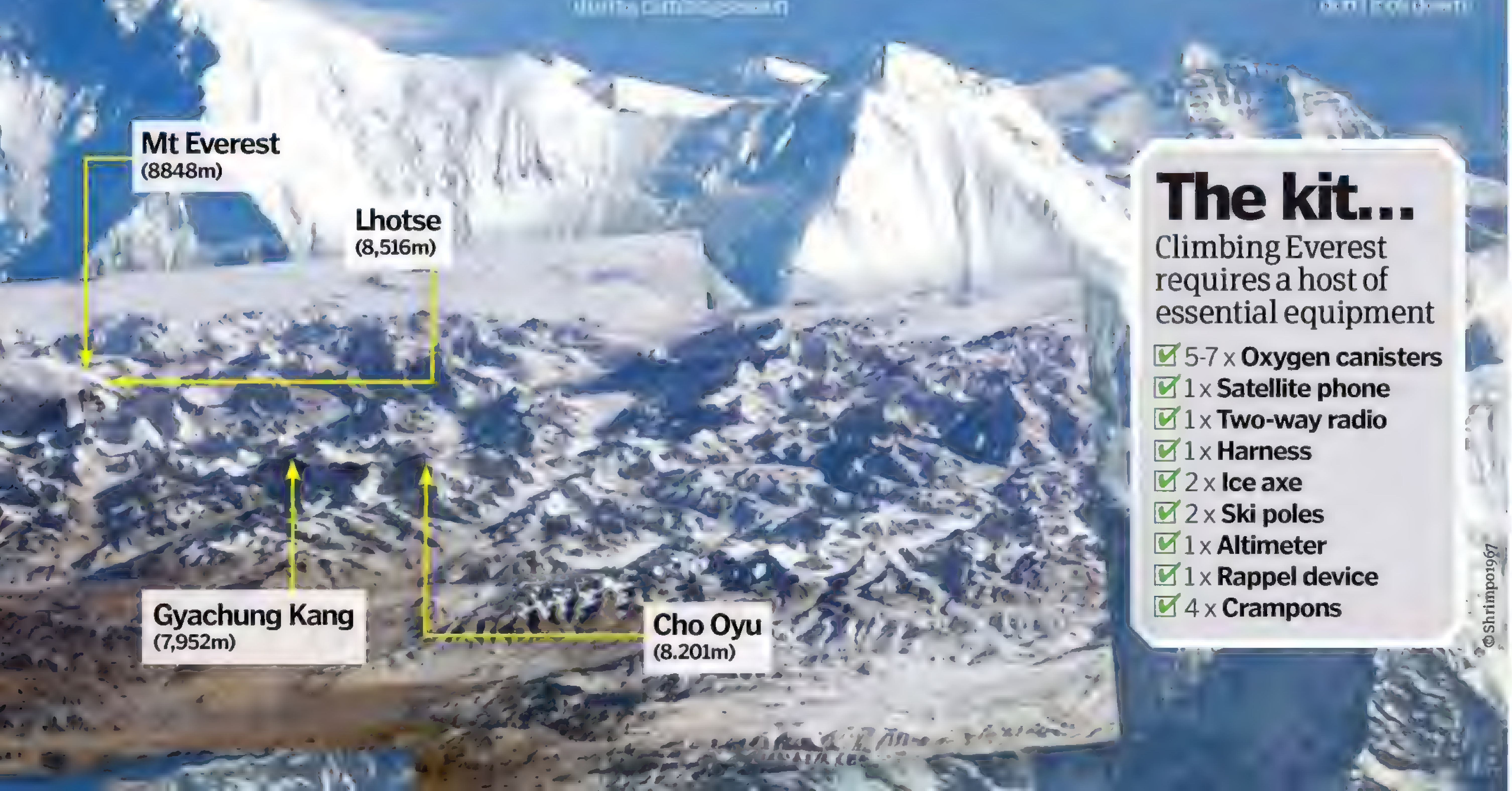
The summit of Everest lit up by the morning Sun

© Luca Galuzzi

Base camp is surprisingly busy during climbing season

© Uwe Gill

Whatever you do don't look down



© Shrimp0967

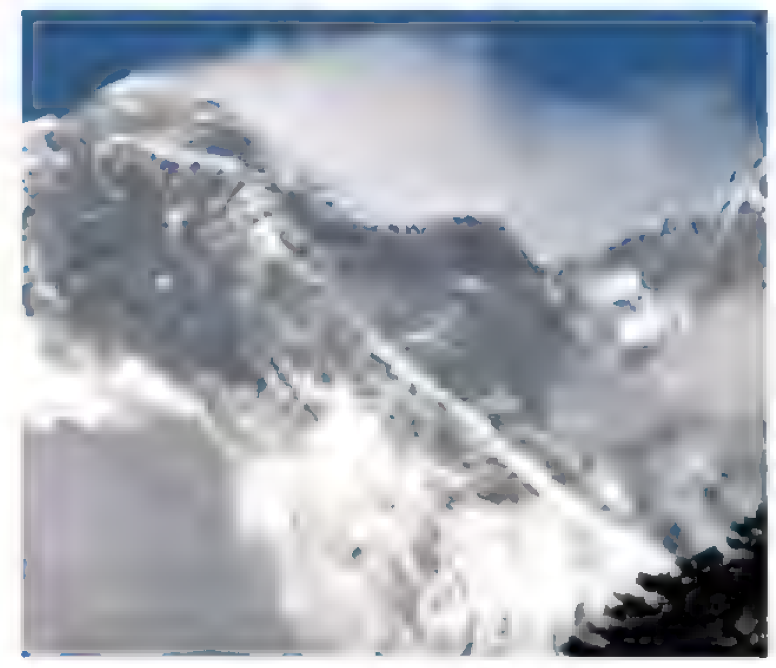
The kit…

Climbing Everest requires a host of essential equipment

- ☑ 5-7 x **Oxygen canisters**
- ☑ 1 x **Satellite phone**
- ☑ 1 x **Two-way radio**
- ☑ 1 x **Harness**
- ☑ 2 x **Ice axe**
- ☑ 2 x **Ski poles**
- ☑ 1 x **Altimeter**
- ☑ 1 x **Rappel device**
- ☑ 4 x **Crampons**

Surviving mountains

A selection of top tips from experienced mountain climbers



1. Training is key
Plan ahead and undertake strict cardiovascular and weight-based training consistently throughout the 12-month run-up to the climb. Taking supplements to your diet is also recommended.

2. Mentally prepare
It is going to be harder than you think. Despite the guide being present you're not going to be dragged up the mountain by them.

3. Be patient
There will be a lot of down-time in order to allow for acclimatisation. Learn to relax while you have the opportunity as you'll need the energy later.

4. Cost it out
Climbing any mountain over 8,000 feet is very costly, both in terms of equipment and permits, and the last thing you should do is compromise on your kit quality.

5. Understand the risks
Many climbers never return from mountains, while others suffer from side-effects such as alpine trench foot, hypothermia and frostbite, or even acute mountain sickness.

Despite the freezing temperatures, Sherpas wear very little

"Although mountains look solid and immovable to us, they're always changing"

Mountain formation

ON THE MAP

10 major mountain ranges

1. Ural Mountains
TYPE: Fold mountain range in Russia and Kazakhstan

2. Altai Mountains
TYPE: Fault-block mountain range in Central Asia

3. Tian Shan
TYPE: Fault-block mountain range in Central Asia

4. Sumatra-Java range
TYPE: Discontinuous mountain range system containing active volcanoes, ranging the length of Sumatra (the Barisan Mountains) and Java

5. Serra do Mar
TYPE: Discontinuous mountain range system on east coast of Brazil, fault-block formation

6. Transantarctic Mountains
TYPE: Fault-block mountain chain that serves as a division between East and West Antarctica

7. Eastern Highlands
TYPE: Discontinuous fold mountain range system dominating eastern Australia

8. Himalayas
TYPE: Fold mountain range system in Asia between India and the Tibetan Plateau

9. Rocky Mountains
TYPE: Fold mountain range in western North America

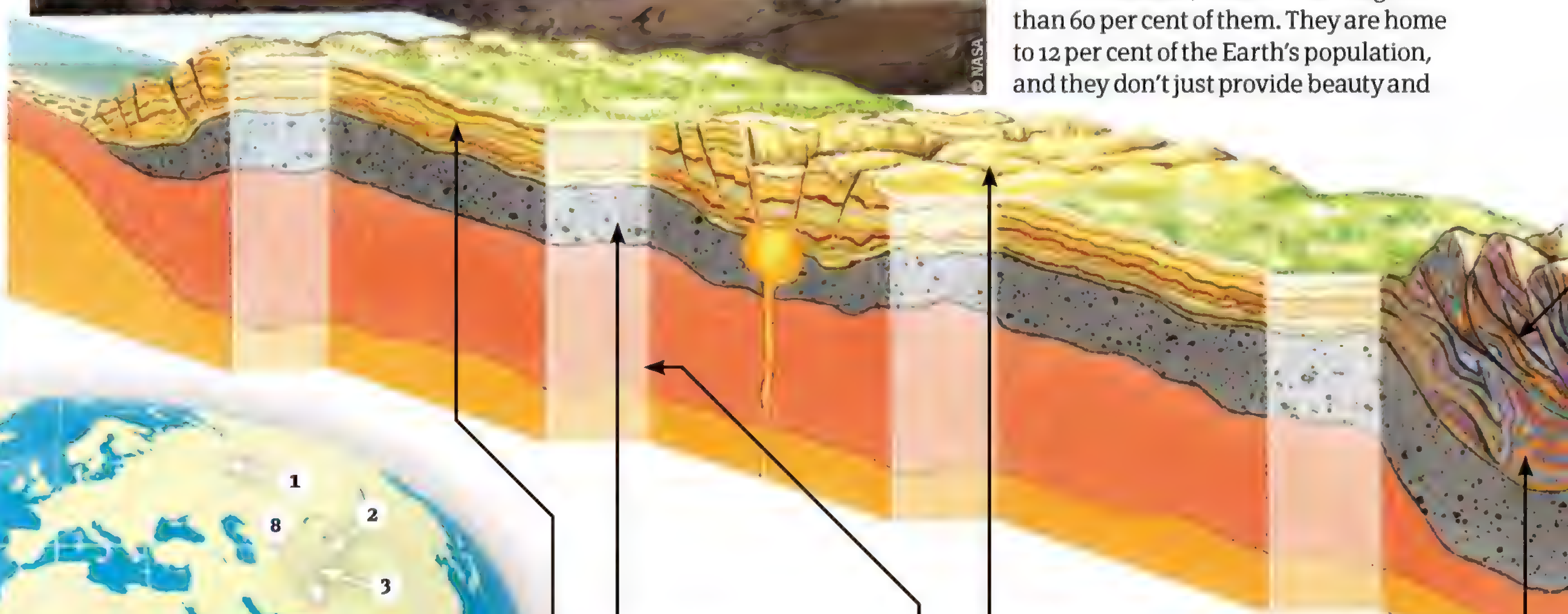
10. Andes
TYPE: Fold mountain range in South America

The Himalayas are home to the world's highest peaks

How many ways can you make a mountain?

Mountains are massive landforms rising high above the Earth's surface, caused by one or more geological processes: plate tectonics, volcanic activity and/or erosion. Generally they fall into one of five categories – fold, fault-block, dome, volcanic and plateau – although there can be some overlap.

Mountains comprise about 25 per cent of our land mass, with Asia having more than 60 per cent of them. They are home to 12 per cent of the Earth's population, and they don't just provide beauty and



Lithosphere
This rocky, rigid layer includes the oceanic and continental crusts and part of the mantle. Tectonic plates reside in this layer.

Continental crust
The outermost shell of the planet comprises sedimentary, igneous and metamorphic rock.

Fault-block mountains
Fractures in the tectonic plates create large blocks of rock that slide against each other. Uplifted blocks form mountains.

Asthenosphere
This semiplastic region in the upper mantle comprises molten rock and it's the layer upon which tectonic plates slide around.

TALLEST: MOUNT EVEREST **8,848m** | SHORTEST: MOUNT WYCHEPROOF (AUSTRALIA) **43m (141ft)**

OLDEST RANGE: BARBERTON GREENSTONE BELT (SA) **3.5bn yrs** | YOUNGEST MOUNTAIN RANGE: HIMALAYAS **60-80m yrs**

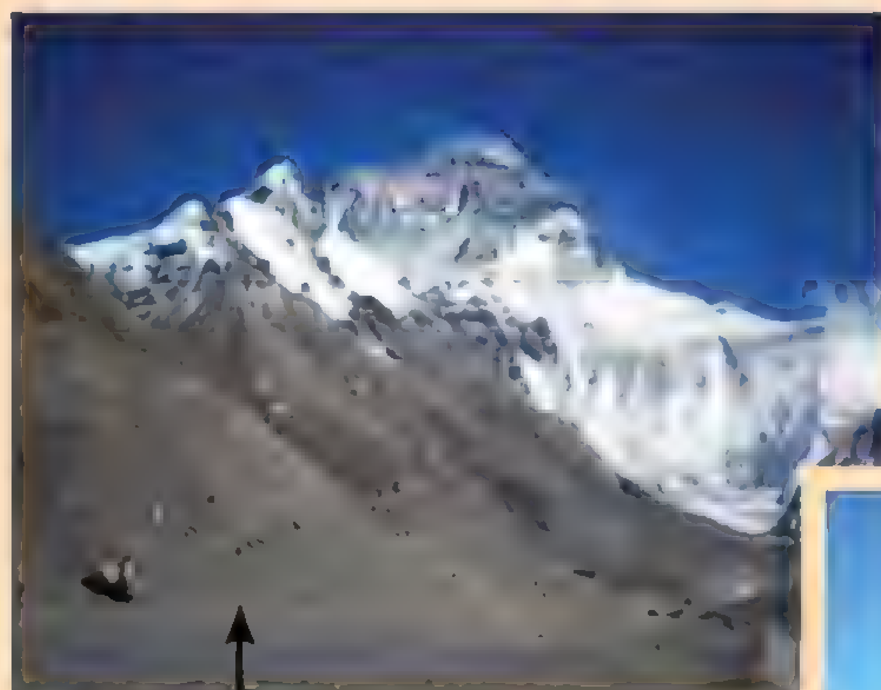
DID YOU KNOW? *There is no universal definition of a mountain – for some it means a peak greater than 300m above sea level*

recreation; more than half of the people on Earth rely on the fresh water that flows from the mountains to feed streams and rivers. Mountains are also incredibly biodiverse, with unique layers of ecosystems depending on their elevation and climate.

One of the most amazing things about mountains is that although they look solid and immovable to us, they're always changing. Mountains rising from activity associated with plate tectonics – fold and fault-block – form slowly over millions of years. The plates and rocks that initially interacted to form the mountains continue to move up to 2cm (0.7in) each year, meaning that the mountains grow. The Himalayas, for example, grow about 1cm per year.

The volcanic activity that builds mountains can wax and wane over time. Mount Fuji, the tallest mountain in Japan, has erupted 16 times since 781AD. Mount Pinatubo in the Philippines erupted in the early-Nineties without any prior recorded eruptions, producing the second largest volcanic eruption of the 20th Century. Inactive volcanic mountains – and all other types of mountains, for that matter – are also subject to erosion, earthquakes and other activity that can dramatically alter their appearances as well as the landscape around us. There are even classifications for the different types of mountain peaks that have been affected by glacial periods in Earth's history. The bare, near-vertical mountaintop of the Matterhorn in the Alps, for example, is known as a pyramidal peak, or horn.

Types of mountain



Fold

This most common type of mountain is formed when two tectonic plates smash into each other. The edges buckle and crumble, giving rise to long mountain chains.

Examples: Mount Everest, Aconcagua

Volcanic

These mountains are created by the buildup of lava, rock, ash and other volcanic matter during a magma eruption.

Examples: Mount Fuji, Mount Kilimanjaro

© DanielCase

Plateau

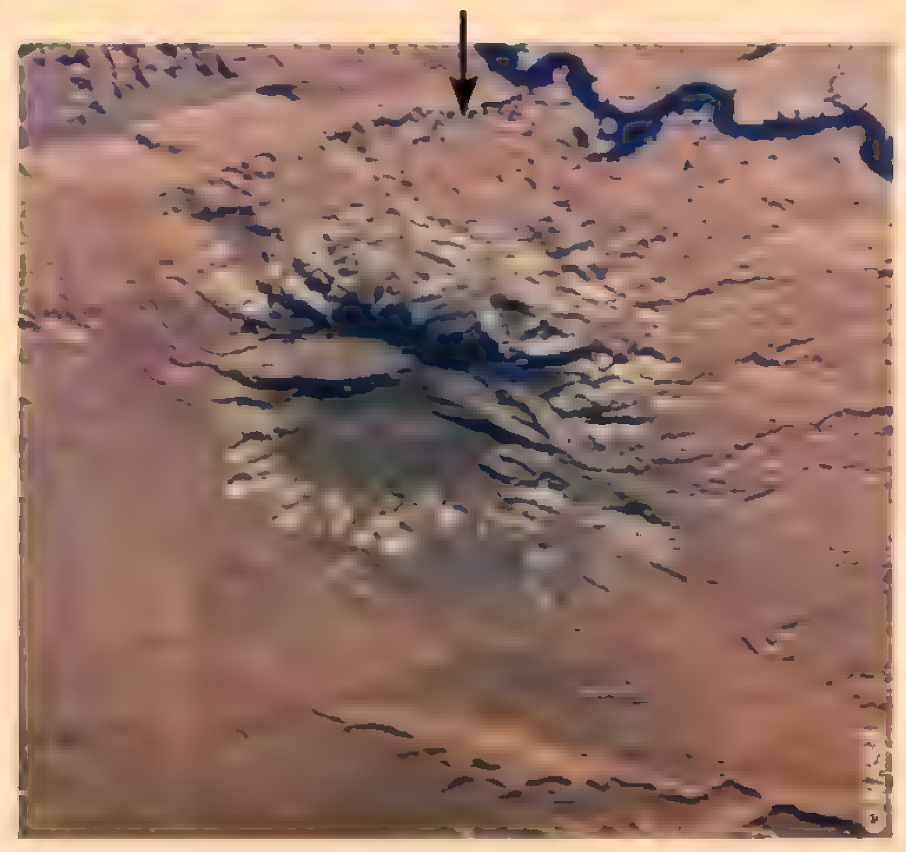
Plateau mountains are revealed through erosion of uplifted plateaux. This is known as dissection.

Examples: Catskill Mountains, Blue Mountains

Dome

These types of mountain also form from magma. Unlike with volcanoes, however, there is no eruption; the magma simply pushes up sedimentary layers of the Earth's crust and forms a round dome-shaped mountain.

Examples: Navajo Mountain, Ozark Dome

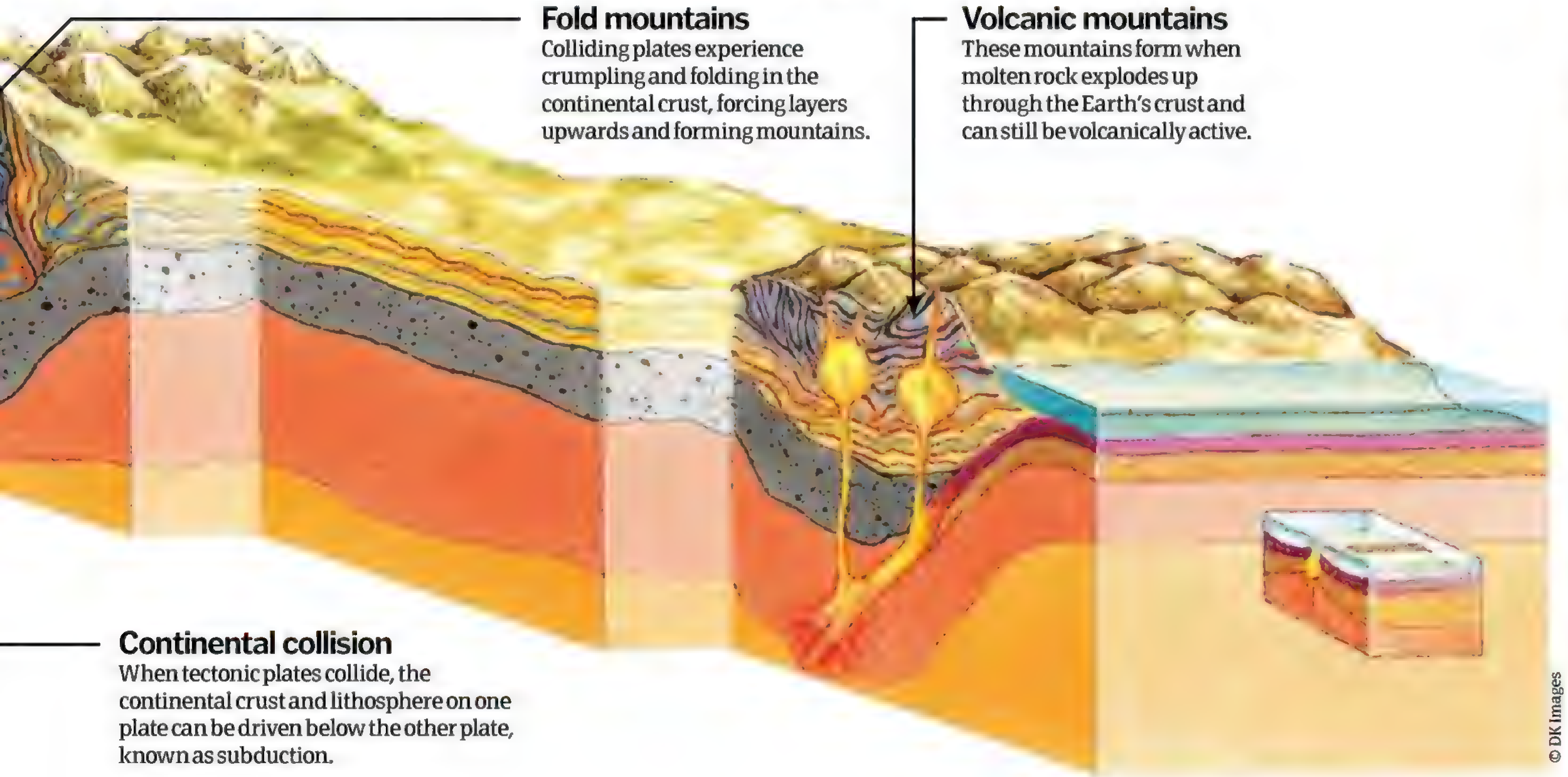


© NASA

Fault-block

Fault-block mountains form when cracked layers of crust slide against each other along faults in the Earth's crust. They can be lifted, with two steep sides; or lifted, with one gently sloping side and one steep side. **Examples:** Sierra Nevada, Urals

Mountains made from below



© DK Images

Mountains are home to 12 per cent of the world's population

Massive marine mountains

If you thought mountain ranges were restricted to land, then think again...

The Mid-Atlantic Ridge is part of the longest mountain range in the world – these mountains just happen to be underwater. Mid-ocean ridges are a result of plate tectonics, and form due to volcanic activity in the oceanic crust. Currents in the Earth's mantle cause magma to heat up, and it is forced through weak spots in the crust. The resulting lava cools into a new layer of crust. This pushes the plates apart and the resulting formation often has a rift, or valley, in the centre where two different plates are being pushed apart. All of these mid-ocean ridges are connected around the world, totalling 80,000 kilometres (50,000 miles) or so in length.

The Mid-Atlantic Ridge by itself is around 10,000 kilometres (6,200 miles) long. It separates the North American tectonic plate (which also includes the Bahamas, Cuba, Greenland and parts of other countries) from the Eurasian tectonic plate. It also separates the South American tectonic plate from the African tectonic plate. Most of the mid-Atlantic plate is underwater, but some of it is actually high enough to appear above sea level. This includes a ridge that contains the island of Iceland, as well as a number of other islands.

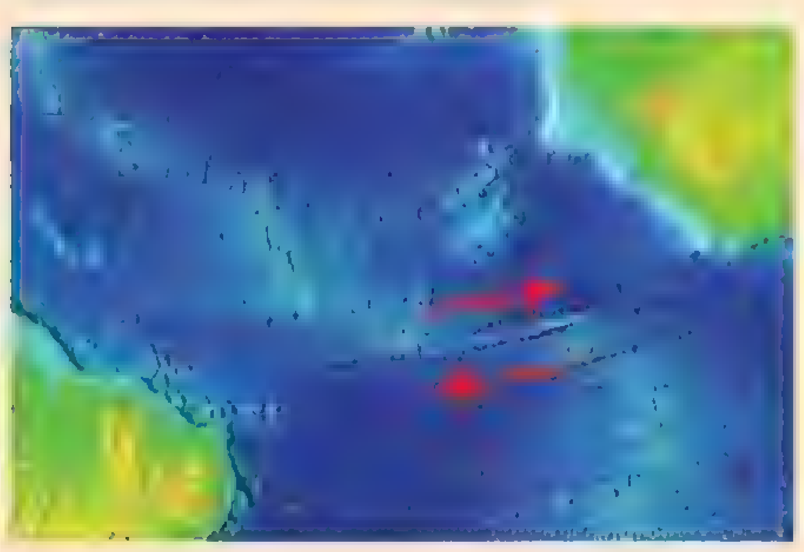
Oceanographers and researchers have thought there was a mountain range in the ocean here since the 1870s, and it was confirmed in 1925 by sonar. It wasn't until the Fifties, however, that we were able to fully understand the unique features hidden in the depths of the mid-Atlantic, and realised just how massive it really was. In addition to the islands, there are numerous deep trenches and valleys as well as extensive seismic activity, which is constantly altering the terrain.

The red boundaries show the tectonic plates that make up the Earth's crust, which are shifting and moving all the time

Mid-Atlantic Ridge key features

1 Romanche Trench

This trench is the third deepest in the Atlantic, and bisects the Mid-Atlantic Ridge around the equator, between Brazil and west Africa. It is about 19km (12mi) wide, 300km (186mi) long and 7.76km (4.82mi) deep. Because of its depth, it plays a key role in water circulation between the east and west Atlantic basins.



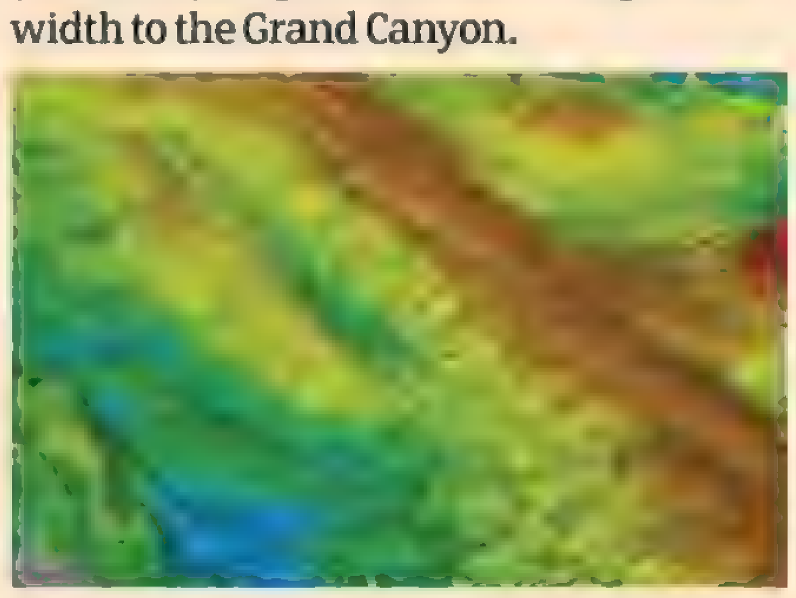
2 Iceland

The island of Iceland in the northern Atlantic Ocean is part of a sub-ridge on the Mid-Atlantic Ridge that's known as the Reykjanes Ridge; this rises 2,110m (6,923ft) from the seabed. Incidentally, Iceland is also on top of a mantle plume, a place where hot rock has risen through the mantle but isn't a part of plate tectonics.

© NASA

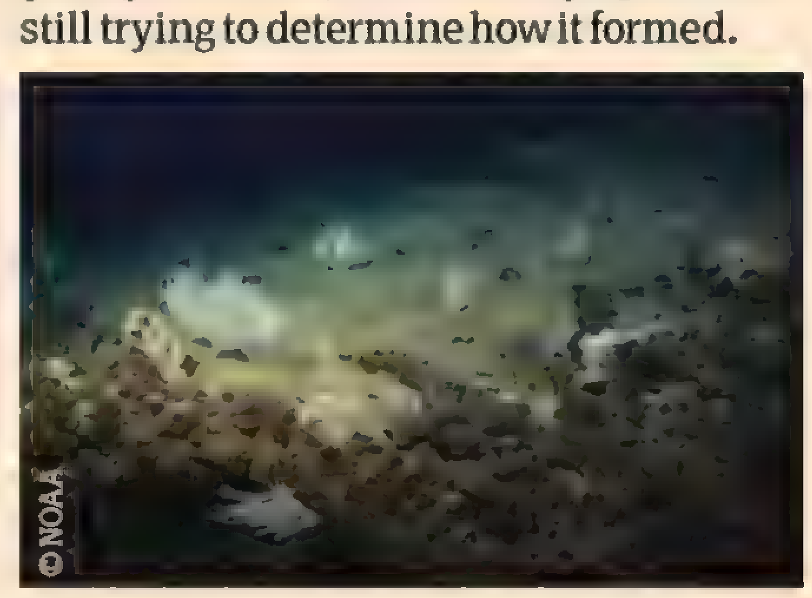
3 Deep rift valley

This valley runs the entire length of the Mid-Atlantic Ridge (approximately 10,000km/6,200mi) and serves as the boundary between the North American and the Eurasian tectonic plates that are separated by the ridge. At 1-3km (0.6-1.8mi) deep, it is similar in depth and width to the Grand Canyon.



4 Atlantis Massif

This huge dome-shaped hill is just west of the centre of the ridge. It's about 1,700m (5,500ft) high and much wider than other hills on the ocean floor. It's very smooth compared to the surrounding terrain, so it must be fairly new (in geological terms), but oceanographers are still trying to determine how it formed.



© NOAA

THE STATS MID-ATLANTIC RIDGE			
LENGTH: 10,000km (6,213mi)	NUMBER OF ISLANDS: 6	SPREADING RATE PER YEAR: 2.5cm (1in)
BELOW SEA LEVEL: 2.5km (1.5mi)	DEEPEST POINT: 7,758m (25,453ft)	YEAR DISCOVERED: 1872

DID YOU KNOW? We think of the seafloor as stable, but it's actually spreading continually due to volcanic/seismic activity

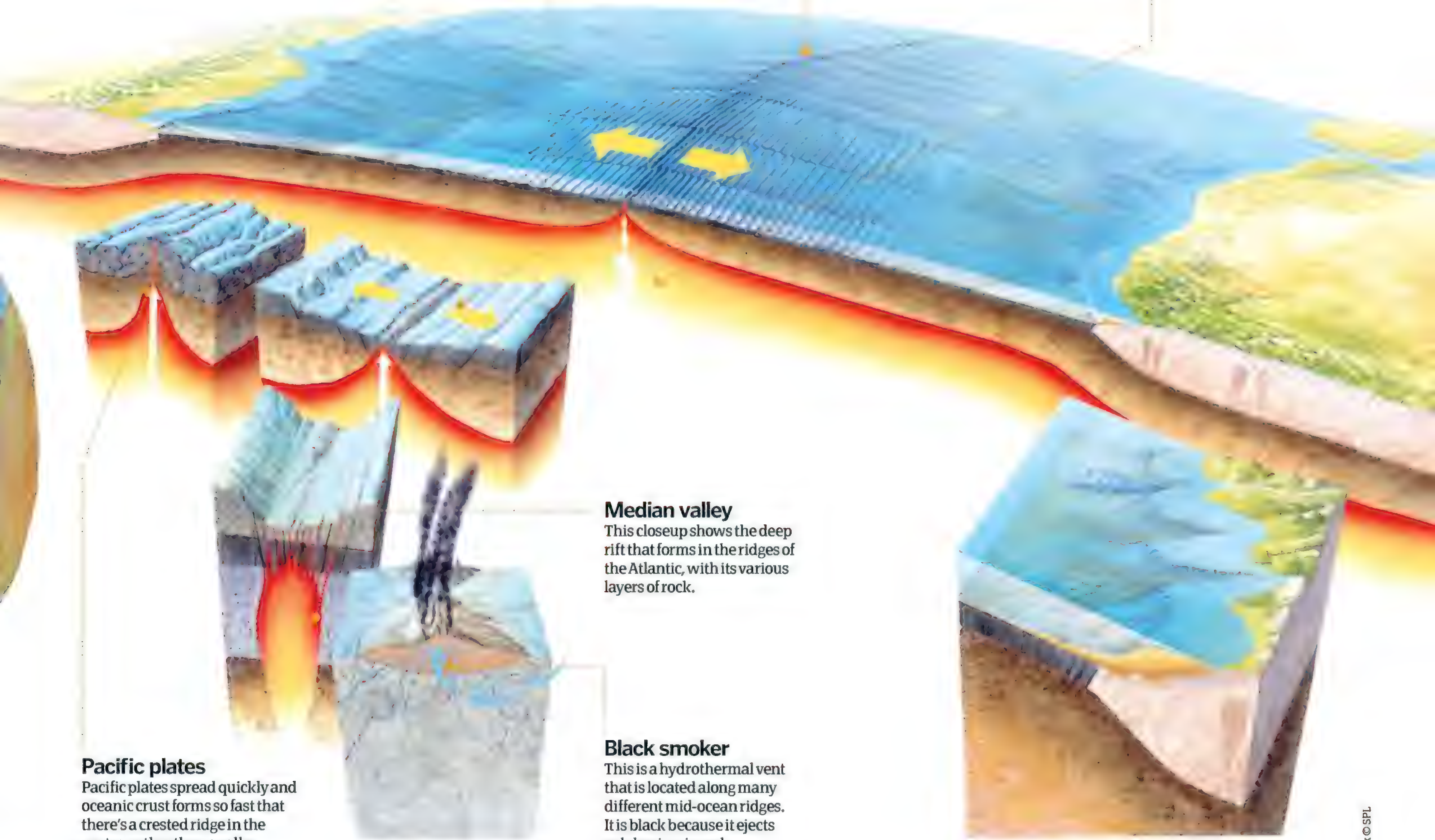
Seafloor evolution

The terrain of the ocean floor is changing all the time due to the ongoing activity occurring in the mantle below the Earth's crust

Atlantic plates
Atlantic plates are slow spreading, which results in a deep valley forming between the plates.

Lava
Lava cools in the ocean and builds up in a ridge.

Molten rock
Magma rises up through weaker spots in the ocean crust.



Median valley
This closeup shows the deep rift that forms in the ridges of the Atlantic, with its various layers of rock.

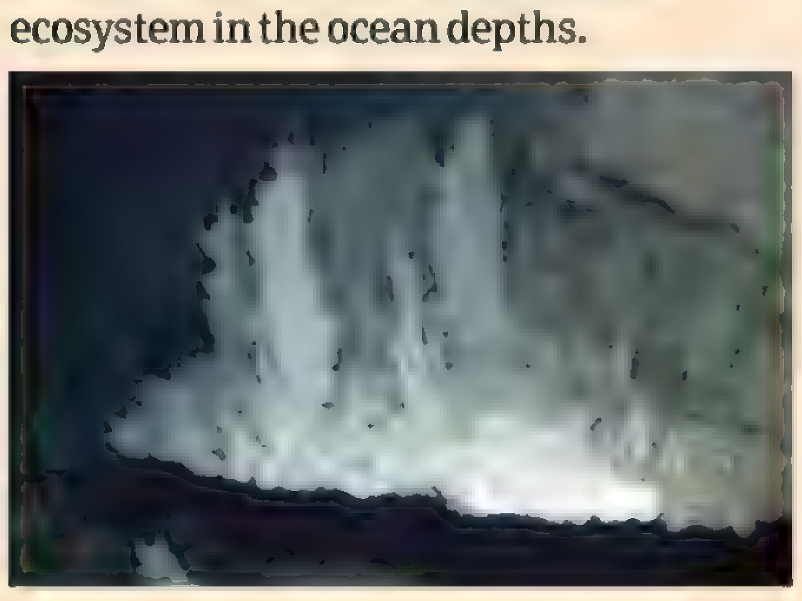
Black smoker
This is a hydrothermal vent that is located along many different mid-ocean ridges. It is black because it ejects sulphuric minerals.

Pacific plates
Pacific plates spread quickly and oceanic crust forms so fast that there's a crested ridge in the centre, rather than a valley.

2 x © SPL

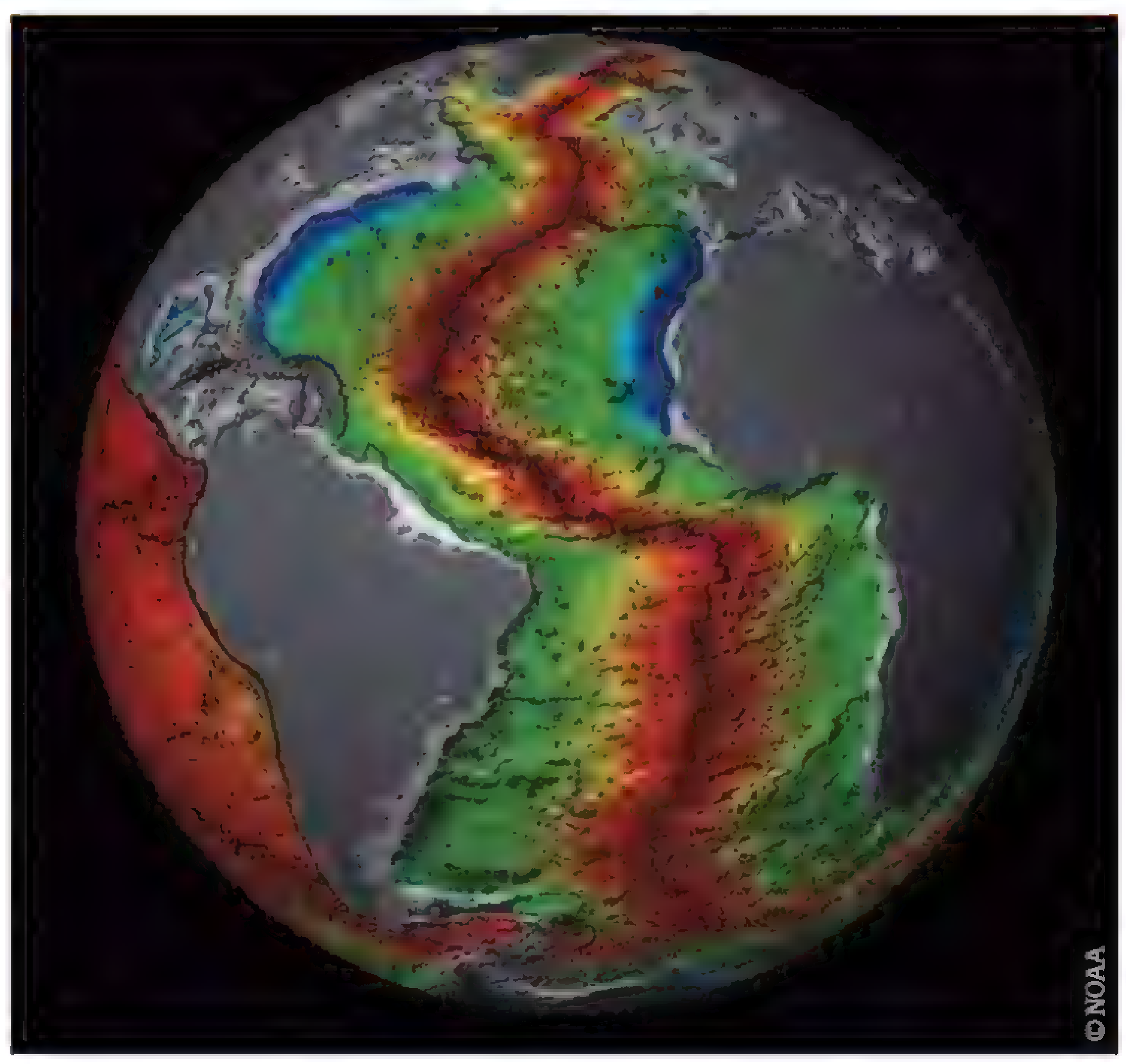
5 Hydrothermal vents

These hydrothermal vents are located in the same region as the Atlantis Massif. They're essentially openings in the crust where geothermally heated water spews into the ocean. They vent a lot of methane and hydrogen into the water, and this has created a unique ecosystem in the ocean depths.



What lies beneath…

The Mid-Atlantic Ridge actually sits on another formation in the ocean, which is called the Mid-Atlantic Rise. This elevation is a sort of bulge off the ocean floor, which is caused by immense pressure in the mantle pushing up through the crust. The Mid-Atlantic Rise is thought to have formed during the Triassic period, dating back to about 200 million years ago. The central valley of the Mid-Atlantic Ridge experiences a lot of earthquakes as well, which is probably also due to the instability in the mantle. Because of the continual seismic and volcanic activity the ocean floor here is slowly but consistently spreading along the ridge at a rate of 2.5 centimetres (one inch) per year.



© NOAA

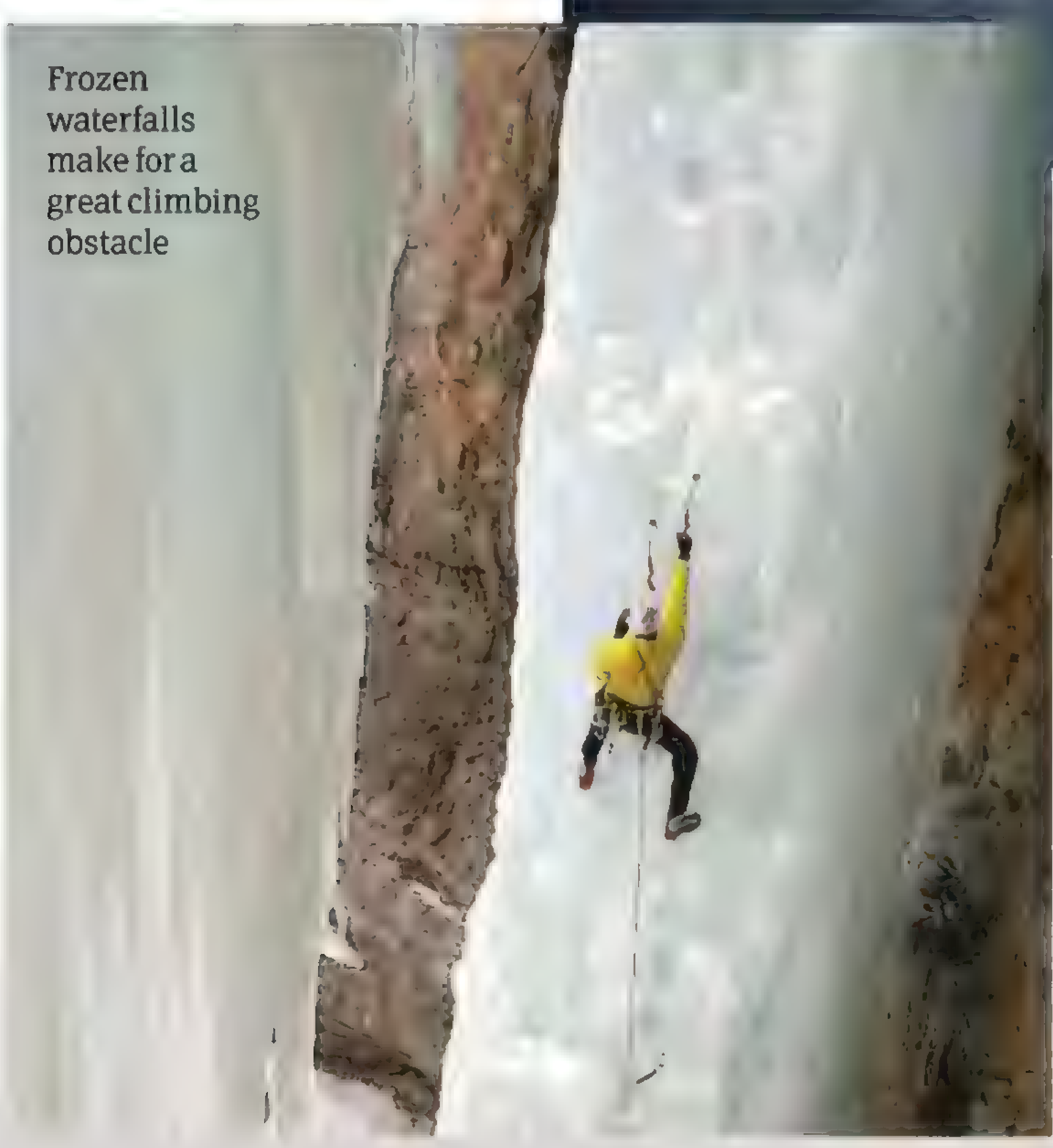
Waterfall formation

How are these dramatic geological river features formed?

The often-breathtaking natural product of vertical erosion, a waterfall occurs in a river's steep upper course high above sea level. A waterfall forms over many thousands of years as river water flows over a band of hard rock lying next to a band of soft rock downstream. The erosive effects of hydraulic action (water pushing air into tiny cracks in the riverbed) and abrasion (rocks scraping over each other) cause the soft rock to erode quicker than the hard. So while the hard rock remains solid for longer, the soft rock below is worn away, lowering the riverbed from that point and forming a step drop.

At the foot of the step, a deep plunge pool forms where water and rocks collect and swirl about, abrading more of the riverbed and less-resistant rock in the process. The harder, overhanging 'cap' rock is gradually undercut and eventually collapses due to its own weight, breaking off into the plunge pool.

Further collapse of the hard rock sees the waterfall itself recede back upstream, creating steep-sided gorges either side of the waterfall.



Frozen waterfalls make for a great climbing obstacle

A waterfall formed by volcano

Located on the border between Argentina and Brazil and surrounded by subtropical rainforest, Iguazu Falls is one of the most impressive waterfall systems on the planet. Part of a World Natural Heritage Site, Iguazu is distinctive because it was formed as a result of a massive volcanic eruption, which left a massive crack in the earth. Though there are many taller and more powerful falls, at 1.67 miles Iguazu is one of the widest, making it an undeniably awesome spectacle. The whole area consists of 275 individual waterfalls spread out across the Iguazu River. A mammoth semicircular waterfall lies at the heart of a series of cascading falls, and the main plunge waterfall, known as Garganta del Diablo, or the Devil's Throat, is 82 metres tall.

Iguazu Falls is a major draw for tourists in South America

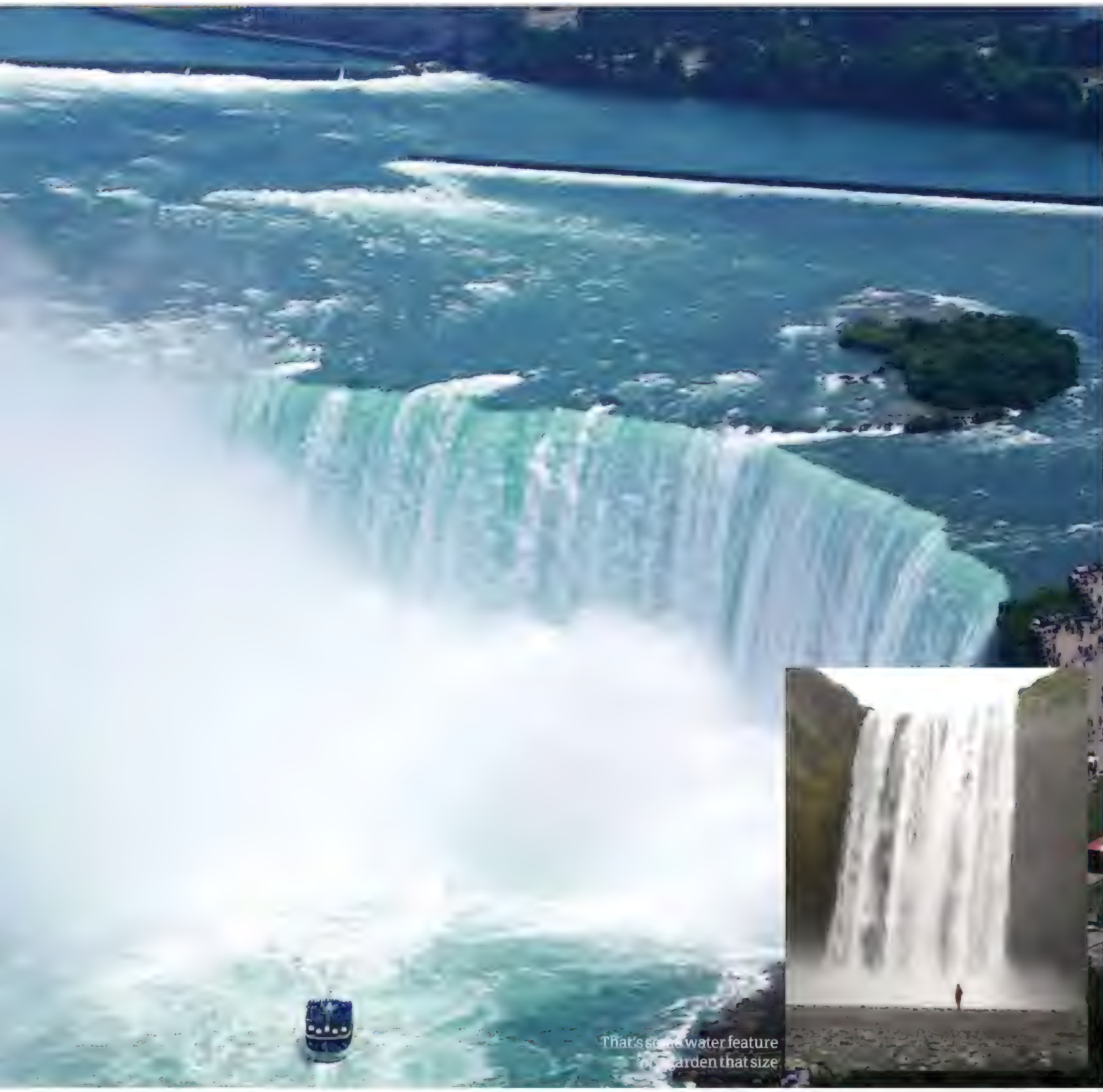
Head to Head WATERFALLS

1. Niagara Falls
Facts: Situated on the US/Canada border, Niagara Falls is undoubtedly the most famous waterfall in the world, yet it stands at a mere 51 metres tall.

2. Victoria Falls
Facts: Named after Queen Victoria who reigned during its discovery, this impressive fall on the Zambia/Zimbabwe border has a total height of 107 metres.

3. Angel Falls
Facts: Found in Venezuela, Angel Falls' total height is a whopping 979 metres, making it the tallest waterfall on Earth, and the world's longest drop.

DID YOU KNOW? *Waterfalls can freeze mid-flow due to freezing temperatures slowing the water molecules down*



That's some water feature for a garden that size

Waterfall creation

What processes happen to make a waterfall

1. Undercutting/overhanging
A layer of resistant hard rock is undercut by the erosion of the softer rock beneath. This forms a step over which the water flows.

2. Plunging
The force of the falling water hitting the soft rock below creates a plunge pool, which is deepened by the abrasion of fallen angular rocks.

3. Collapsing
Further erosion, worsened by splashback from the falling water in the plunge pool, causes the overhanging hard rock to eventually collapse under its own weight.

4. Receding
As this cycle of erosion and collapsing continues, the waterfall steepens and recedes back upstream, creating a steep-sided gorge and an increasingly tall waterfall.

TYPES OF… WATERFALLS

There are ten different ways to classify waterfalls

1 Block
Occurring over a wide stream where the waterfall is wider than it is tall. It spills over like a wide sheet of water.

2 Cascade
Flows either over a series of small steps in the rock in quick succession, or over a rugged sloping surface.

3 Curtain
Found on a wide section of stream where the fall is taller than it is wide. These falls tend to narrow during periods of low discharge.

4 Fan
Occurring when the width of the water spilling over increases as it descends, making the base appear much wider than the top.

5 Horsetail
Found on vertical waterfalls, the falling water is in constant or semi-constant contact with the bedrock.

6 Plunge
Water spills over vertically, usually losing contact with the bedrock altogether. Often known as a cataract waterfall.

7 Punchbowl
The flow of water is squeezed through a narrow opening and is then blasted out and down into a pool.

8 Segmented
If the stream is broken into multiple channels this will cause several falls to occur side by side.

9 Slide
Slide waterfalls flow down over a smooth, sloping bedrock surface while maintaining contact with the bedrock.

10 Tiered
Tiered waterfalls form when several distinct drops occur one after the other, in close succession.

Learn more

For more information about different waterfalls around the world, head on over to **www.world-waterfalls.com/** where you can read about waterfalls from every corner of the Earth, and choose your favourite!

The water

Rain falling today has spent billions of years travelling between Earth's clouds, oceans and ice

The water – or hydrological – cycle is the Earth's water recycling system. Since water rarely escapes the planet or arrives from space, the water cycle keeps rivers relentlessly flowing into the oceans and the atmosphere supplied with clouds and rain. Without it, life simply couldn't exist.

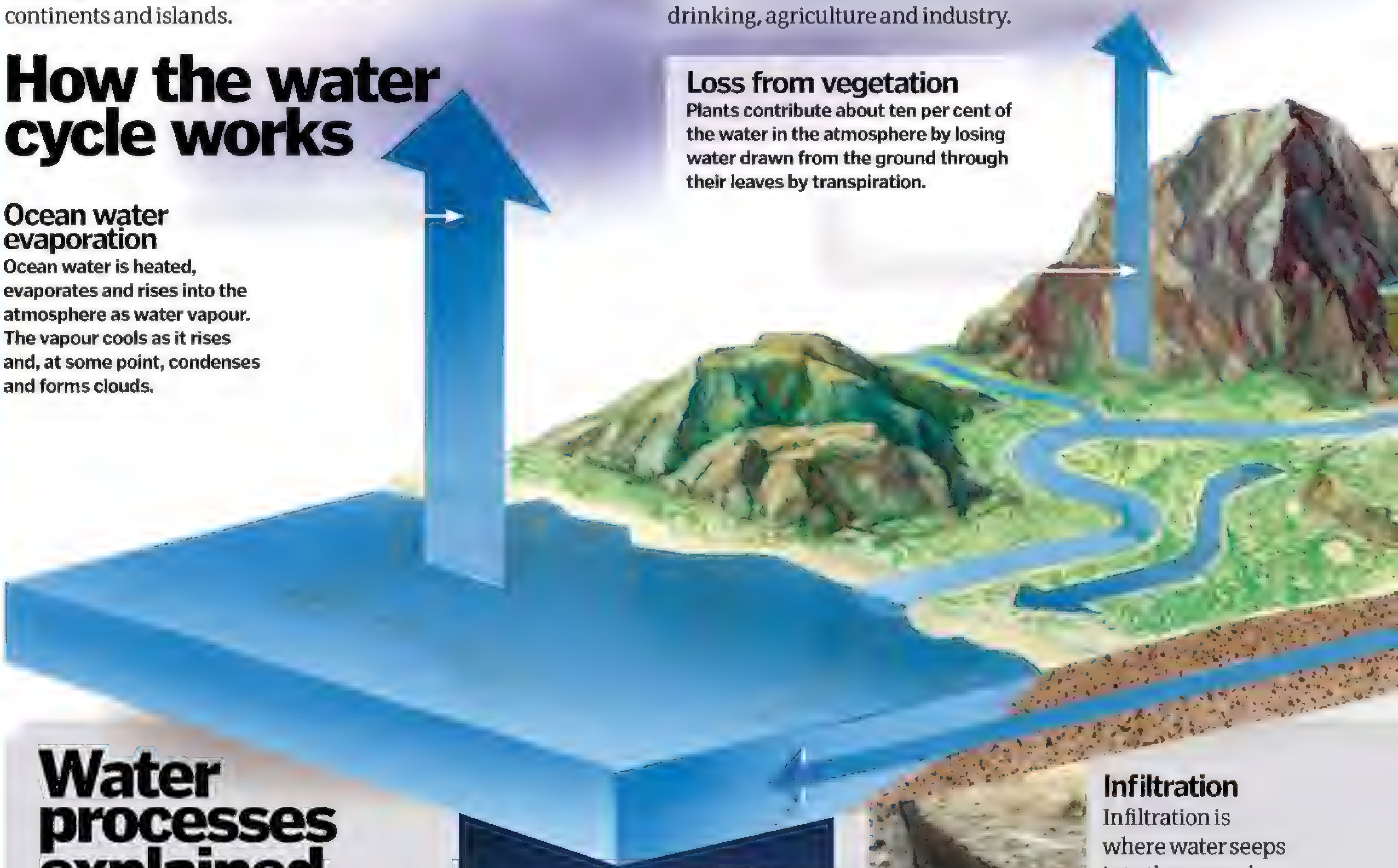
The water cycle circulates water between the oceans and atmosphere, sometimes via the land. When ocean water is heated, it turns into water vapour, which rises into the atmosphere and is carried by winds. The vapour cools at some point and forms clouds. Around 78 per cent of the rain, snow and other forms of precipitation falling from these clouds goes straight back into the ocean. The rest falls over the Earth's continents and islands.

Some of this water runs into rivers and lakes and is carried back to the sea. Water also seeps back to the oceans through deep soil and rocks, becoming the Earth's groundwater. Water falling as snow over the polar ice sheets can be buried, sometimes for millions of years, until it reaches the sea via slow-moving glaciers.

Water that stays in shallow soil can be lifted back into the atmosphere when it warms. Alternatively, plants may suck up soil water through their roots and return it to the atmosphere through their leaves. When animals eat plants, they take the water into their bodies and expel it into the air in their breath.

Humans are increasingly altering the water cycle on land by building cities and flood controls, and capturing water for drinking, agriculture and industry.

How the water cycle works



Loss from vegetation

Plants contribute about ten per cent of the water in the atmosphere by losing water drawn from the ground through their leaves by transpiration.

Ocean water evaporation

Ocean water is heated, evaporates and rises into the atmosphere as water vapour. The vapour cools as it rises and, at some point, condenses and forms clouds.

Water processes explained

Condensation

When you breathe on a cold window and it fogs up, you're seeing condensation in action. It's the process by which water vapour in the air turns back into liquid water when it cools down. Atmospheric water vapour condenses on salt, smoke and dust particles to form clouds.

Infiltration

Infiltration is where water seeps into the ground rather than running across it. Once in the ground, the water stays in shallow soil layers or moves deeper to form groundwater. Dry, loose soils on flat ground will absorb more water than steeply sloping hard surfaces or already wet soil.

Ancient science
1 People first mentioned the water cycle around 2,000 years ago. One of the oldest Hindu scriptures, the Chandogya Upanishad, said "rivers… lead from sea to sea".

Drop to drink
2 Most people get water from rivers and lakes, which form just 0.014 per cent of the world's water. The rest is mainly in the oceans (96.5 per cent), ice or underground.

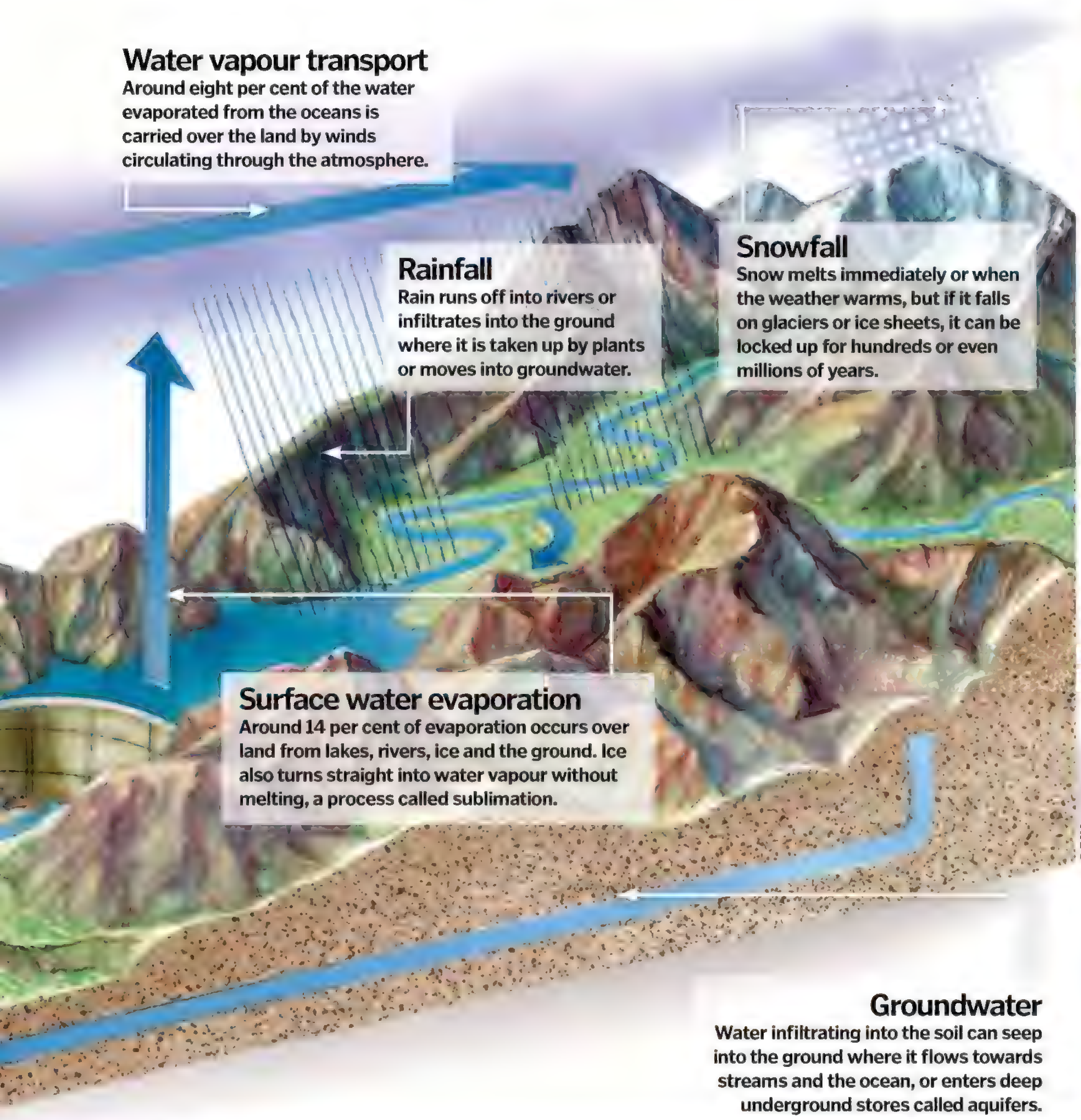
Olympic deluge
3 A small thunderstorm can produce, on average, 2,000 tons of rain in just 30 minutes. That's enough to fill an Olympic-sized swimming pool.

Earliest water
4 Liquid water may have existed on Earth for 4.4 billion years. The water in your glass is almost as old as our planet and significantly older than the dinosaurs.

Slow moving
5 Water can spend more than 10,000 years locked up in deep groundwater or the polar ice sheets, but just a few days in the atmosphere.

DID YOU KNOW? The Sun powers the water cycle, moving around 15.5 million tons of water through the atmosphere every second

cycle




The River Indus is now some 30 kilometres wide in places

When the water cycle lets us down

Floods affect tens of thousands of people each year, as is evident from this year's devastating monsoon flooding across Pakistan. The flood, which has affected some 20 million people so far, was the result of the heaviest monsoon rains in the area for generations. On 8 August the River Indus burst its banks, sweeping away entire communities. While it's normal for Pakistan to receive half its annual rainfall (250-500mm) during the monsoon months of July and August, the country was reportedly bombarded with 300mm on 29 July alone. The Met Office suggests several possible reasons for the unusually heavy rains, including changes to upper atmosphere airflow, active monsoon systems, and La Niña (El Niño in reverse).


Serious floods, like those seen in Pakistan during July and August, can cause catastrophic destruction

Runoff

Water flowing down tarmac roads into curb-side drains after a storm is an example of the process of runoff. Rain that doesn't evaporate or infiltrate into soil or rock also flows down small channels as runoff. The channels merge into streams that, eventually, join rivers flowing downhill to the sea.

Evaporation

Wet clothes hung outside dry by evaporation, the process by which liquid water turns into vapour when heat energy breaks bonds between its water molecules. Soaking a T-shirt keeps you cool on a hot day because since evaporation uses up heat energy from the air, it reduces nearby temperatures.

Precipitation

Precipitation is a catch-all term for water falling from clouds to the earth.

It covers rain, snow, hail and so on. Precipitation happens when water vapour condenses on airborne particles as droplets. These grow bigger by, for example, collisions until they become so heavy they fall to the ground.

Transpiration

Plants – like humans – breathe out water vapour, a process called transpiration. During transpiration, water drawn into a plant's roots is carried to the leaves where it evaporates. How much plants transpire varies depending on air temperature, humidity and incoming sunlight. Higher temperatures and stronger sunlight mean more transpiration.

“The load is transported down the river in four ways, depending upon the size of the material”

How rivers

The river’s fascinating processes and intriguing features from start to finish

Beginning life in the mountains, rivers form from streams created through precipitation or springs of water that are sourced from groundwater that has percolated the earth. These streams, known as tributaries, then flow rapidly through V-shaped valleys, over rocky terrain and over rock edges as waterfalls. This is the first of three stages any river goes through and is known as the upper course or youth.

By the second stage, known as the middle course or maturity, many tributaries will have joined together to form the main body of water that makes up the river. The river meanders at a medium speed across narrow flood plains, which are areas of flat land lying either side of a river. Flood plains are formed when successive flooding causes sediment to be deposited on the banks.

As the river follows its course it carries with it a load, which is made up of rocks, stones, sand and other particles. It is the load that causes erosion as the materials crash against the banks of the river. The load is transported down the river in four ways, depending upon the size of the material. Traction is the rolling of the largest particles across the riverbed, whereas saltation is the bouncing of those slightly smaller. Finer materials are carried along through suspension and some are dissolved within the water and are moved through solution.

The final stage of a river is the lower course, predictably sometimes known as old age. By this time the river has slowed considerably as it heads towards the sea across broad flood plains, finally ending at what is known as the mouth – where the river finally joins the ocean. Deltas are formed as the river deposits its load.

Waterfall

These are formed over thousands of years as the river erodes away soft rock; the more the soft rock is eroded the steeper the drop becomes.

Flood plain

This is the flat land either side of the river, where floodwater goes and sediment is deposited when the river floods.

Meander

As the river travels its course its load erodes the sides and carves out bends known as meanders.

The river system

Delta

This is where the river slows down as it reaches the sea and as the water slows it deposits its load. This deposited sediment forms the delta.

Mouth

The mouth is the end of the river, where it widens and joins with the sea. All rivers end this way.

Deltas, estuaries and the river mouth

The mouth of a river signifies the end of its course and is where the river meets the sea. The ‘D’ shaped area of sediment that forms at the river mouth is called a delta. Deltas are built up from the bed as the river slows and deposits its load as it reaches the end of its course. The river tends to split as it travels over a delta.

Estuaries are also found at the mouth of a river. In these areas the fresh water of the river meets and mixes with the salt water of the sea. Estuaries are affected by the tide, and the combination of salt and fresh water provides a diverse habitat for many plants and animals.

The delta of the Atchafalaya River on the Gulf of Mexico


LARGEST

1. Amazon
Location: Brazil
Containing 20 per cent of the planet's fresh water, the Amazon is the largest river in the world based upon the volume of water it carries.


HOLIEST

2. Ganges
Location: India
Hindus make pilgrimage to India's largest river south of the Himilayas to bathe in its water, which is believed to wash away sins.

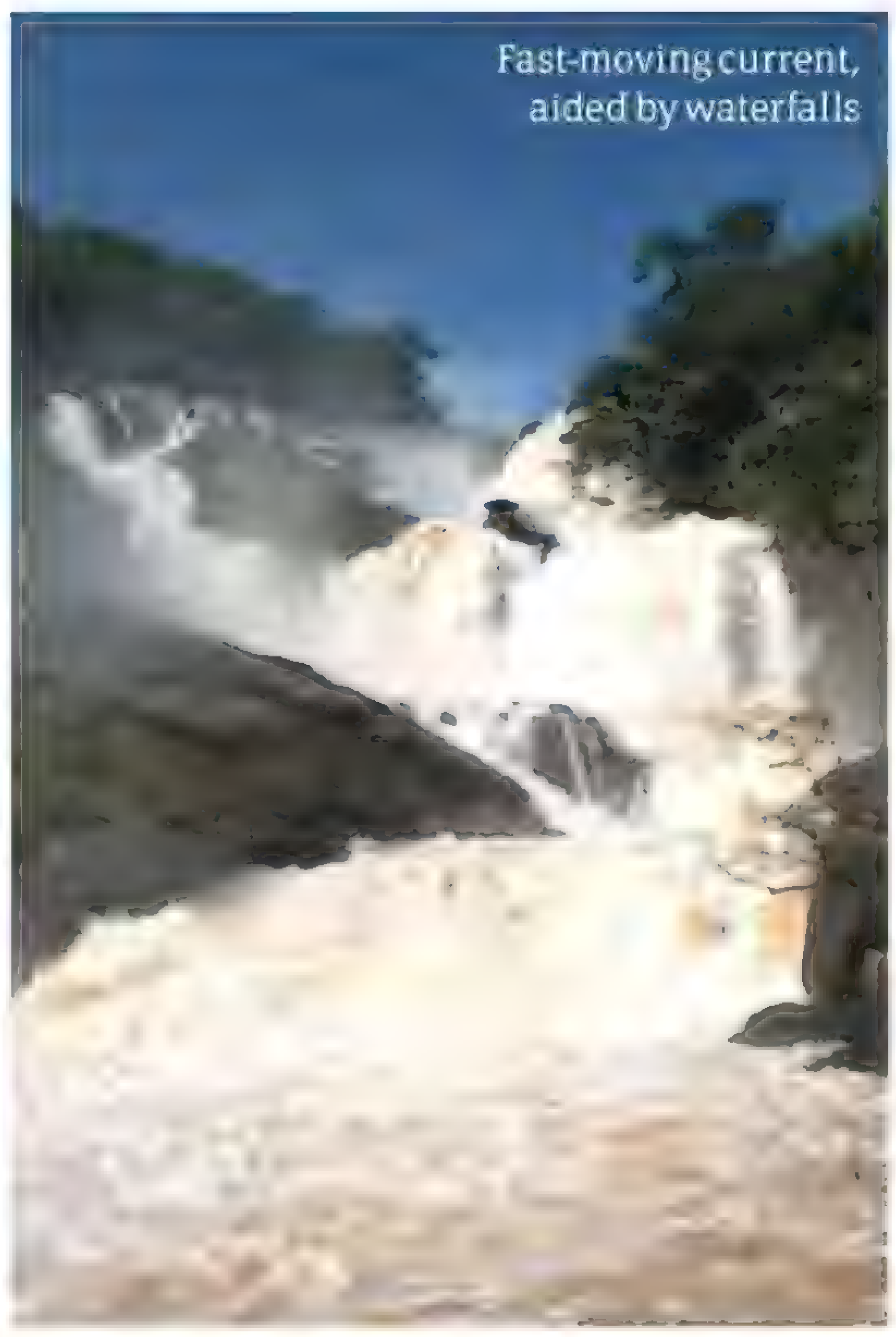

SHORTEST

3. D River and Roe River
Location: USA
A long controversy resulted in two 200-foot rivers being awarded the title of shortest river in the world.

DID YOU KNOW? We all live in a river basin. Even if you don't live close to a river, all land drains to a river system

work

© Science Photo Library


Fast-moving current, aided by waterfalls


A river in the Yamal Peninsula, Siberia that's produced oxbow lakes

Oxbow lakes

Oxbow lakes are crescent- or horseshoe-shaped lakes situated at the side of a flowing river. They are formed from river meanders and are the result of lateral erosion cutting into the bends of the river's course where the river is flowing at its fastest. This eventually leads to the two bends joining together and altering the river's course. Deposition also plays a role as sediment builds up on the outside of the bend where the river flow is much slower. As the river breaks through and the bends join, the sediment builds up to cut off the meander and an oxbow lake is formed.

Stage one

As the water flows around the meander it flows fastest at points 1, leading to the materials carried by the river crashing into (and therefore eroding) the bends.

Stage two

The river flows slowest at points 2, which leads to deposition of sediment. The continuous erosion at points 1 has led to breakthrough, where the curves of the meander have joined together, changing the flow of the river's course.

Stage three

More deposition at point 3 has led to a crescent-shaped lake being completely separated from the river. This lake is known as an oxbow lake and in time will become a wetland, followed by a meadow where trees and plants will develop.

Cave creation

How do huge parts of the Earth get hollowed out?

Caves can form anywhere whether it's in the surface of the Earth, underwater or even inside mountains. In fact, any lump of rock has the potential to turn into a cave because they're created by erosion, which can happen by a number of means.

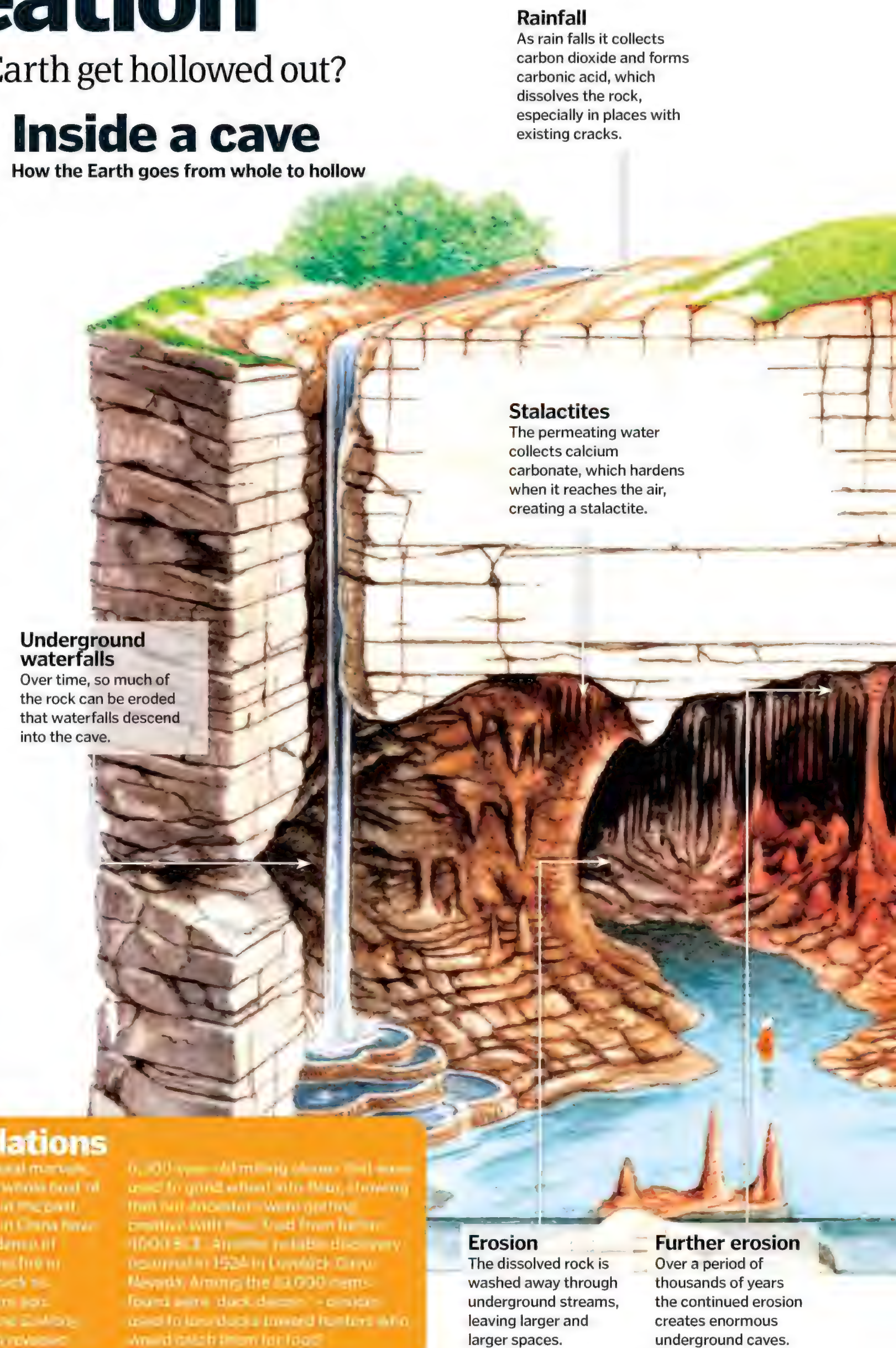
The most common kind of cave is called a solution cave. These tend to be made of rocks such as limestone or gypsum, as they dissolve faster in water than other kinds of rock. Water falling as rain collects carbon dioxide from the atmosphere before descending through the ground. The carbon dioxide mixed with rainwater can form carbonic acid, which is a key ingredient in dissolving the rock, especially in places where there is an existing fissure. Further erosion and collapse transforms these cracks into networks of tunnels and caves. The water will either stay in the base of the cave once it reaches rock that it can't dissolve, or flows out through a hole to begin the whole process again.

Some of the most incredible formations in cave structures are stalactites and stalagmites. Stalactites are the pointy shards that descend from the roof of a cave. These are created when the dripping rainwater collects calcium carbonate on its way through the rock. Once it reaches the open space the calcium carbonate solidifies. This builds up as water drips along the stalactite before hardening. Stalagmites are made of calcium carbonate too, but build from the base of the cave upward if the water has dripped down before becoming solid.

Underwater and overground caves are formed in similar ways. Rock is repeatedly attacked by a force of nature, such as ocean tides, winds or sand. This bombardment wears away at the rock, creating a dent that gets steadily bigger until a cave is formed.

Inside a cave

How the Earth goes from whole to hollow



Cave revelations

[illegible] in 1924 in Lovelock Cave, Nevada. Among the [illegible]

STRANGE BUT TRUE
MODERN CAVEMAN

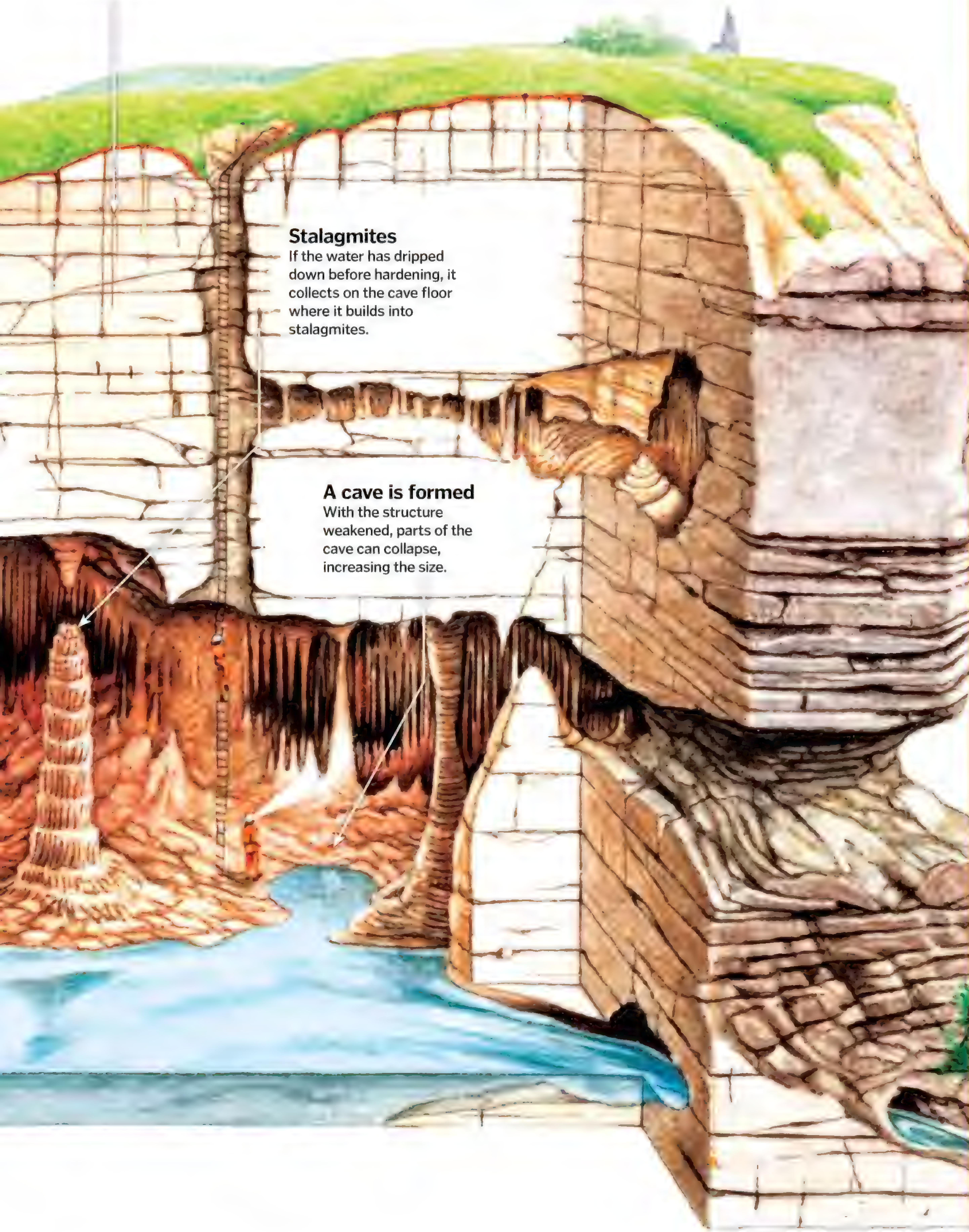
What is inside a Lanzarote lava cave?

A House B Restaurant C Bouncy castle

Answer:
César Manrique, Lanzarote's most famous artist, lived inside a system of volcanic bubbles that were formed by a 1730 volcanic eruption. It was his studio for 24 years before housing the César Manrique Foundation, an organisation that aims to promote the arts.

DID YOU KNOW? Cavemen rarely lived in caves. They would use them for shelter but built huts out of wood, mud and animal skins

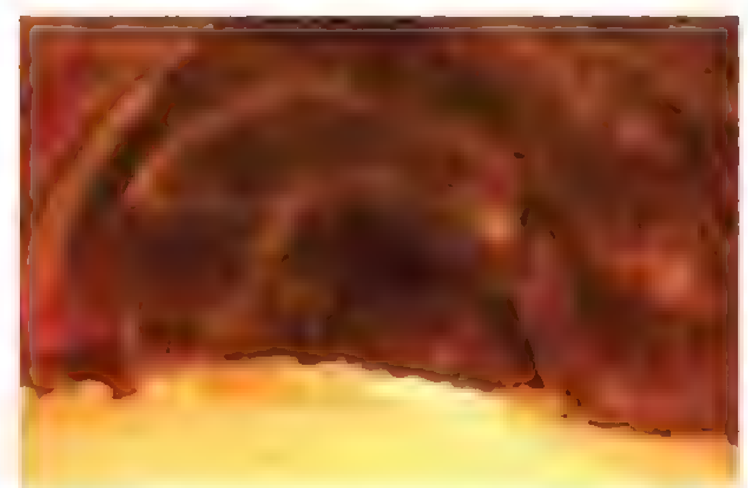
"Some of the most incredible formations in cave structures are stalactites and stalagmites"



Four main types of cave

Solution cave
This is the most common kind of cave in the world. Formed from water moving through carbonate or sulphate rock, these types of cave grow to form some of the largest caverns on Earth.

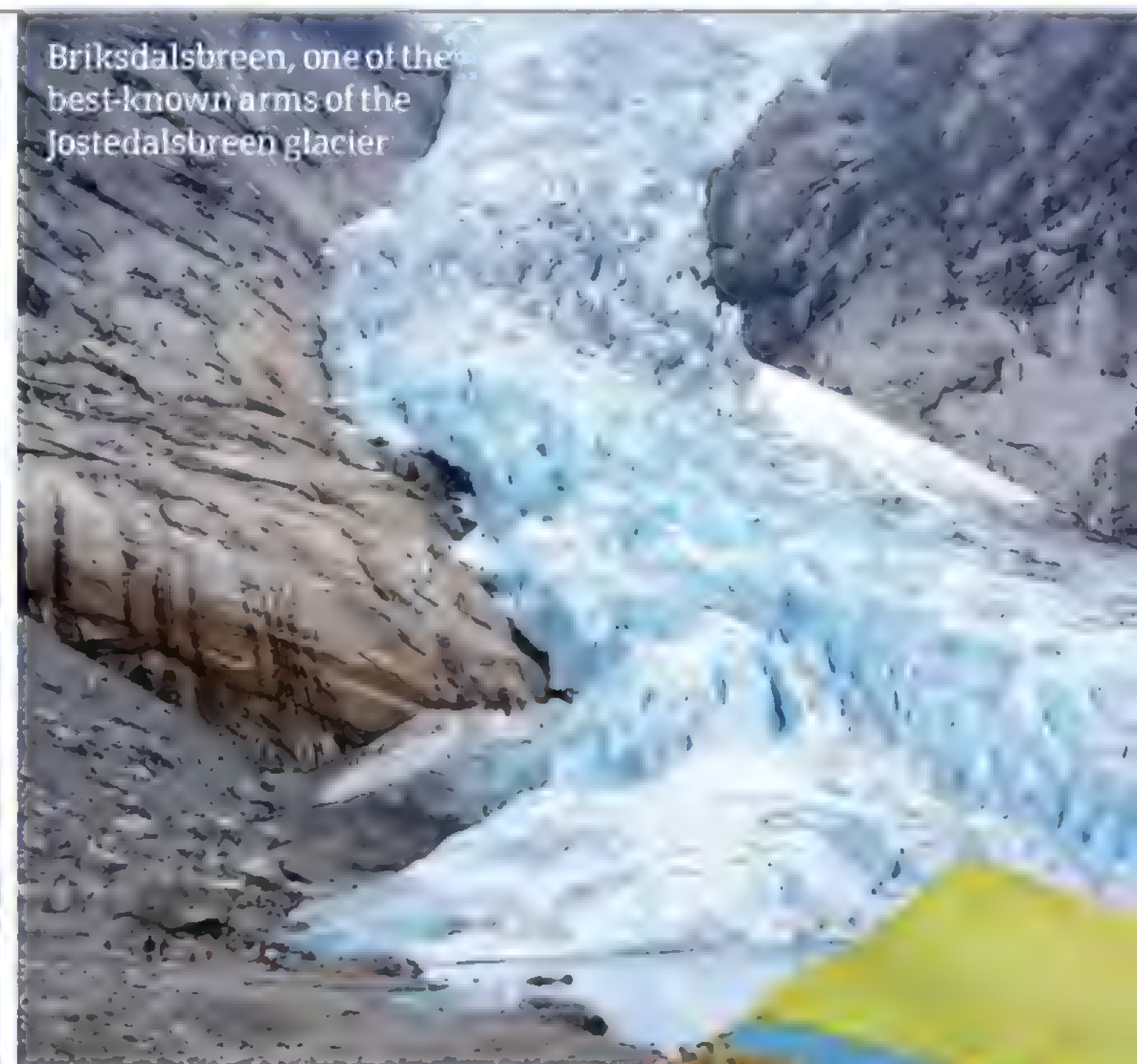
Lava cave
Created when lava is flowing along a path and part of it cools and hardens. This leaves the still-molten lava inside to continue flowing, ultimately resulting in hollow lava tubes.



Glacier cave
The most common cause is melt water running through, or under, the glacier. This widens crevices and carves out chutes, which will then increase in size during the summer months.

Sea cave
Underwater and coastal rocks are constantly battered by waves. This action erodes the weaker parts of the rock. Some of these get flooded and become underwater cave systems.

Glaciers in Wrangell St Elias National Park, Alaska



Briksdalsbreen, one of the best-known arms of the Jostedalsbreen glacier

Glacier power

Discover the awesome Earth-shaping power of gigantic rivers of ice

Glaciers are huge rivers or sheets of ice, which have sculpted mountain ranges and carved iconic peaks like the pyramid-shaped Matterhorn in the Swiss Alps. The secret of this awesome landscape-shaping power is erosion, the process of wearing away and transporting solid rock. Glacial erosion involves two main mechanisms: abrasion and plucking. As glaciers flow downhill, they use debris that's frozen into the ice to 'sandpaper' exposed rock, leaving grooves called 'striations'. This is the process of abrasion. Plucking, however, is where glaciers freeze onto rock and tear away loose fragments as they pull away.

Today glaciers are confined to high altitudes and latitudes, where the climate is cold enough for ice to persist all year round. During the ice ages, however, glaciers advanced into valleys that are now free of ice. Britain, for example, was covered by ice as far south as the Bristol Channel.

You can spot landforms created by ancient ice. Cirques are armchair-shaped hollows on mountainsides, which often contain lakes called 'tarns'. They're also the birthplaces of ancient glaciers. During cold periods, ice accumulated in shady rock hollows, deepening them to form cirques. When two cirques formed back-to-back, they left a knife-edge ridge called an 'arête'. Pyramidal peaks were created when three or more cirques formed. Eventually the cirque glacier spilled from the hollow and flowed downhill as a valley glacier. This glacier eroded the valley into a U-shape, with steep cliffs called 'truncated spurs'. When the glacier melted, tributary valleys were left hanging high above the main valley floor.

Hard rock outcrops in the valley were smoothed into mounds orientated in the direction of ice movement. Rock drumlins are shaped like whalebacks, adopting a smooth, convex shape. Roche moutonnée have a smooth upstream side, and a jagged downstream side formed by plucking. Where valley rocks varied in strength, the ice cut hollows into the softer rock, which filled with glacial lakes known as paternoster lakes.

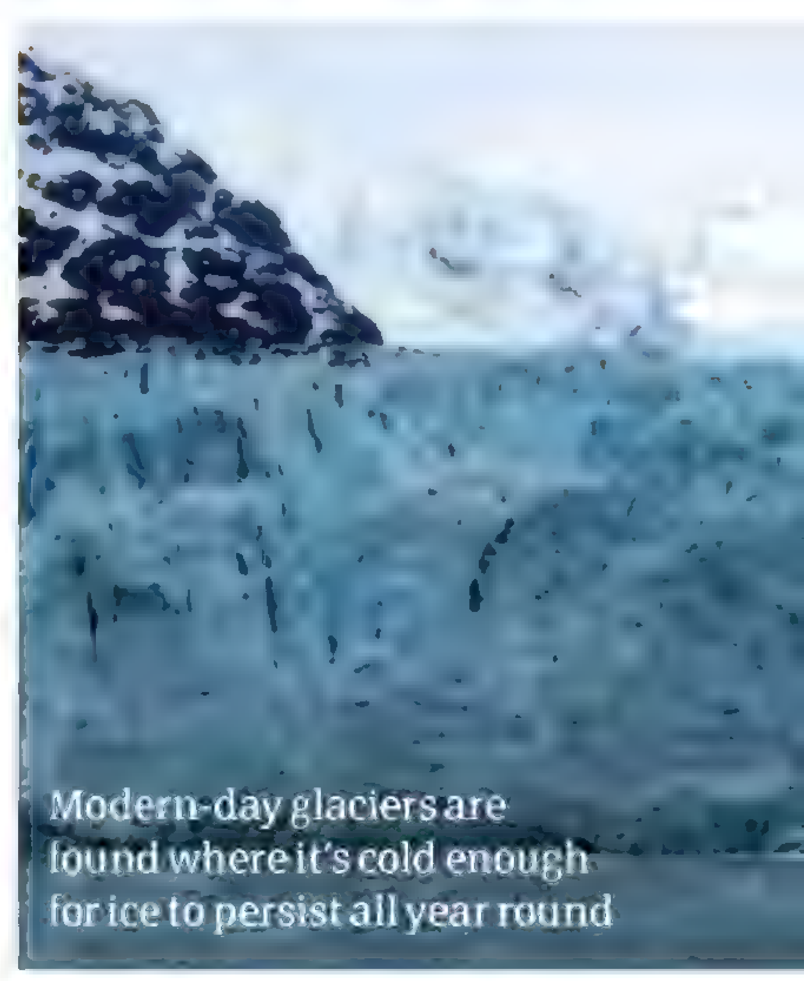
© DK Images

8. Snout

The end of the glacier is called its snout, perhaps because it looks like a curved nose. The snout changes position as the glacier retreats and advances.

2. Medial moraine

A medial moraine is a debris ridge or mound found in the centre of a valley, formed when two tributary glaciers join and their lateral moraines merge.



Modern-day glaciers are found where it's cold enough for ice to persist all year round

1. Landscape Arch, USA
This delicate natural arch – Earth's third largest – is only 2m (6.5ft) thick at its narrowest, but spans a whopping 90m (295ft).

2. Transgondwanan Supermountains, Gondwanaland
Nutrients eroded from a giant mountain range 600 million years ago may have helped Earth's first complex life to develop.

3. Grand Canyon, USA
The Grand Canyon was eroded into the Colorado Plateau by the Colorado River, as mountain building uplifted the plateau.

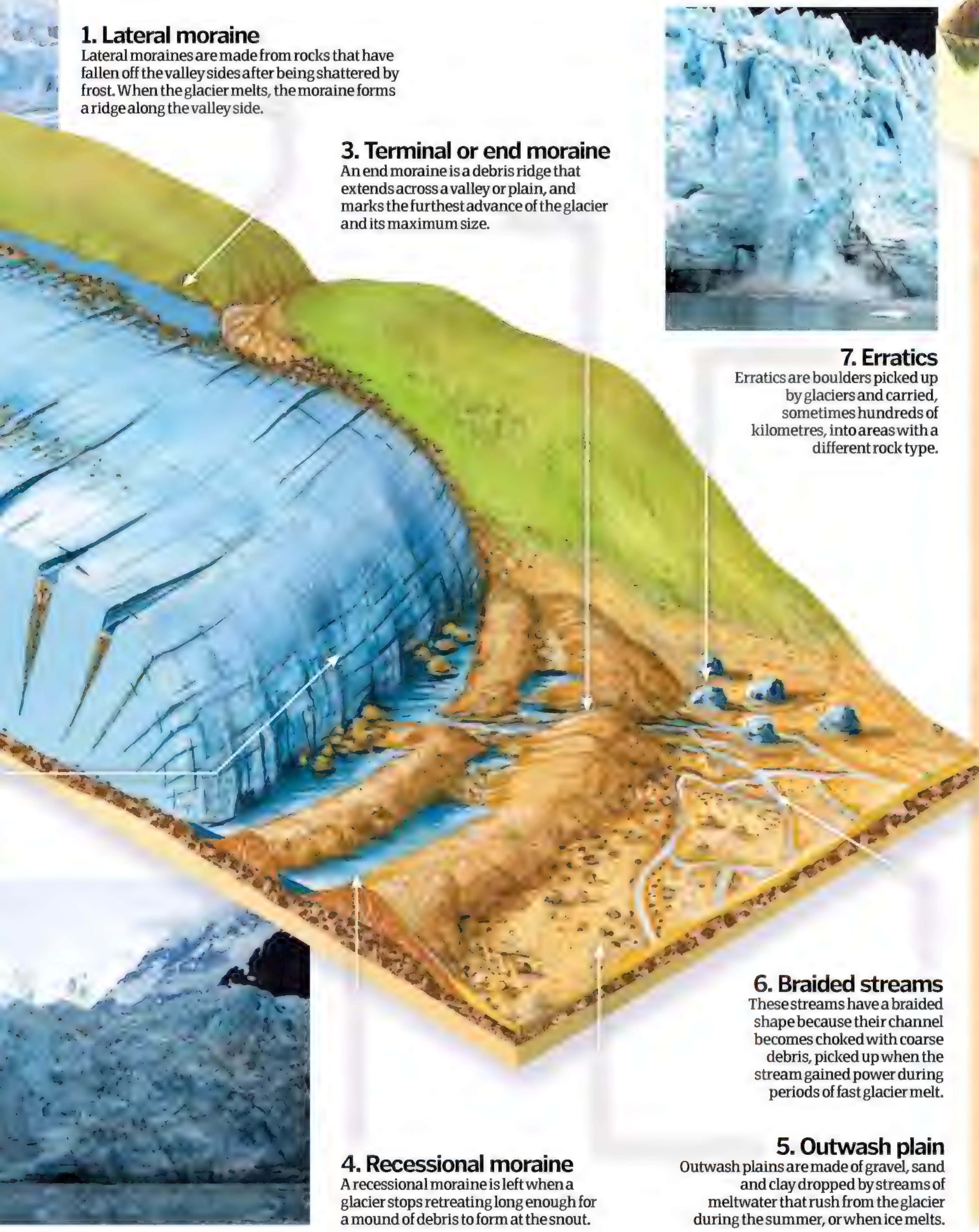
DID YOU KNOW? Ten per cent of the world's land is covered by ice, compared to about 30 per cent during the last ice age

Spotter's guide to lowland glaciers

When you stand at the bottom – or snout – of a valley glacier, you can see landforms made of debris dumped by the ice. The debris was eroded further up the valley and transported downhill, as if on a conveyor belt. Meltwater rushing under the glacier sculpts the debris heaps.

The snout is the place in the valley where the glacier melts completely. This changes over time. If the glacier shrinks, it leaves a debris trail behind. Should it grow again, it collects and bulldozes this debris. To understand why the snout moves up and downhill, you need to see glaciers as systems controlled by temperature and snowfall. On cold mountain peaks, snow accumulates faster than the glacier melts. As ice flows into warmer lowlands, melting begins to exceed accumulation. The snout advances or retreats depending on whether inputs of snow exceed ice loss from the system by melting.

1. Lateral moraine
Lateral moraines are made from rocks that have fallen off the valley sides after being shattered by frost. When the glacier melts, the moraine forms a ridge along the valley side.



3. Terminal or end moraine
An end moraine is a debris ridge that extends across a valley or plain, and marks the furthest advance of the glacier and its maximum size.

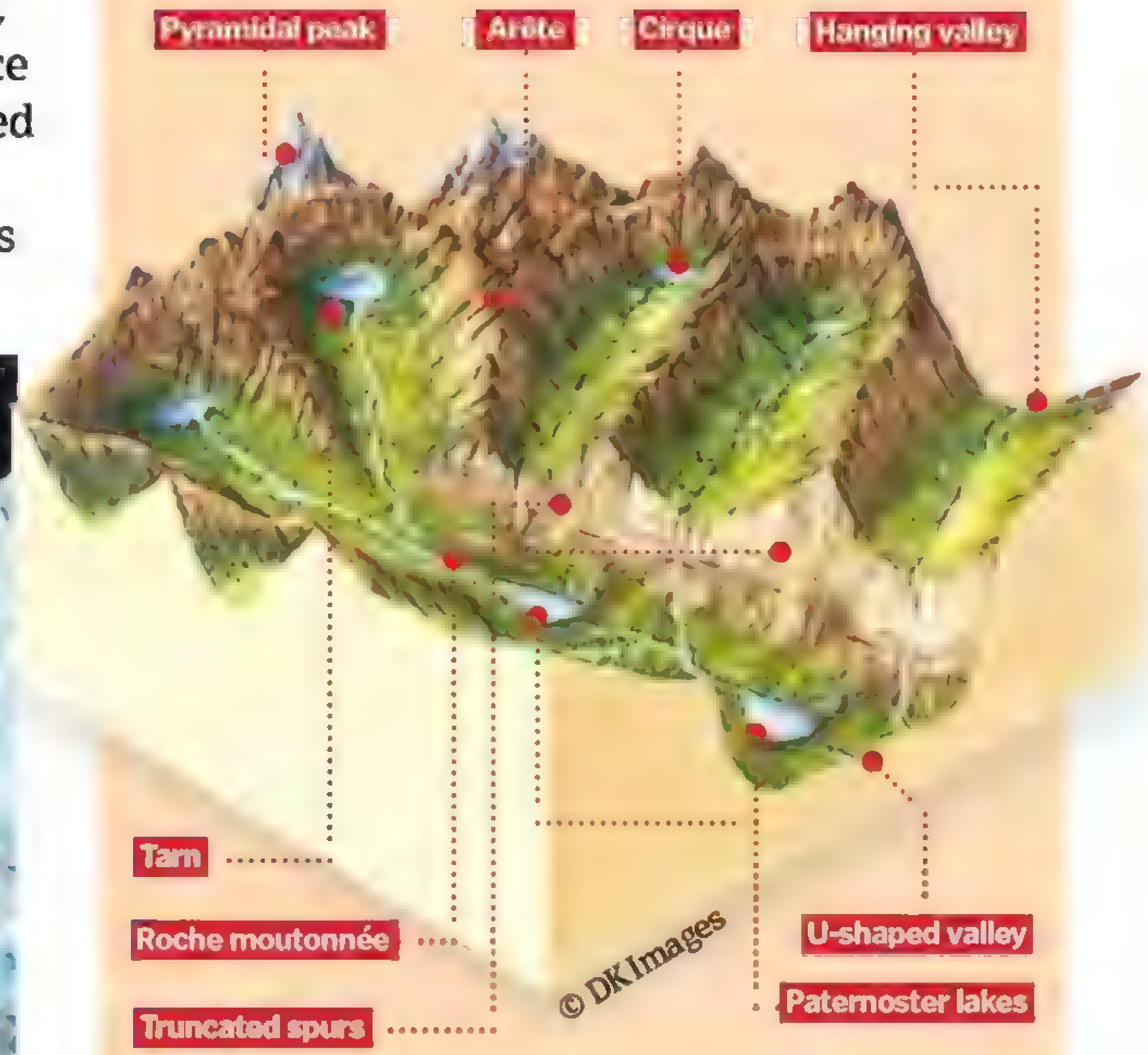
7. Erratics
Erratics are boulders picked up by glaciers and carried, sometimes hundreds of kilometres, into areas with a different rock type.

6. Braided streams
These streams have a braided shape because their channel becomes choked with coarse debris, picked up when the stream gained power during periods of fast glacier melt.

4. Recessional moraine
A recessional moraine is left when a glacier stops retreating long enough for a mound of debris to form at the snout.

5. Outwash plain
Outwash plains are made of gravel, sand and clay dropped by streams of meltwater that rush from the glacier during the summer, or when ice melts.

Inside an ice-carved valley




An aerial shot of a glacier

How does a glacier move?

Glaciers can only move, erode and transport debris if they have a wet bottom. Polar glaciers are frozen to the bedrock all year round and typically move around 1.5 metres (5 feet) per year, as ice crystals slide under gravity. In temperate climes like the European Alps, however, glaciers can slide downhill at 10-100 metres (30-330 feet) per year, due to the fact that meltwater forming under the glacier during mild summers acts as a lubricant.

If meltwater accumulates under a glacier, the ice can race forwards at up to 300 metres (990 feet) per day. During the fastest recorded surge, the Kutiah Glacier in Pakistan sped more than 12 kilometres (7.5 miles) in three months.

"Resilient life forms have adapted to survive the harsh environment"

SURVIVING THE ANTARCTIC

Why the coldest continent on the planet is a surprising hotspot for both scientific research and wildlife...

Antarctica is Earth's coldest, driest and windiest continent, but many resilient life forms have adapted to survive the harsh environment. Among them is Earth's tallest penguin, the largest mammal and the Antarctic icefish – the only bony animal with transparent blood.

The coldest temperature ever officially recorded was on a high snow plateau in Antarctica, at an altitude of around 3.5 kilometres (two miles) – over twice the height of Britain's biggest peak, Ben Nevis. Around 99 per cent of the land surface is covered with ice and air temperatures can be so extremely cold that atmospheric water vapour freezes to form ice crystals. These crystals catch the sunlight as they fall, and sparkle like diamonds, hence why they've gained the nickname 'diamond dust'.

High altitude renders Antarctica considerably colder than its northern polar counterpart, the Arctic. Air temperature falls by approximately 6.5 degrees Celsius (11.7 degrees Fahrenheit) with each kilometre (0.6-mile) rise in elevation. Antarctica is also Earth's fifth-largest continent, and the vast interior receives little heat from the ocean, which is warmer than the ice.

If the climate wasn't extreme enough, Antarctica experiences 24-hour darkness for a couple of months in midwinter. The continent straddles the South Pole and in late June – southern winter – the pole is tilted away from the Sun. Even in summer, most incoming sunlight is absorbed by Earth's atmosphere before it can warm the ground.

Still, unlikely as it may seem, animals and plants survive in Antarctica's ice-free regions. In the windswept McMurdo Dry Valleys, the continent's biggest ice-free area, fungi and algae manage to thrive inside the insulated blanket of sandstone and granite rocks.

The continental coast and Antarctic Peninsula are host to only two flowering plant species. The biggest creatures include mites and primitive insects called springtails. Just one to two millimetres (0.04-0.08 inches) long, they have natural antifreeze in their blood, and they feed on a variety of moss, lichens and other tiny plant life available to them.

5 TOP FACTS
JUST DESERTS

Antarctic
1 Antarctica is Earth's largest desert with a land area of 14mn km² (5.4mn mi²). The tiny amount of annual snowfall here is equivalent to rainfall in the Sahara Desert.

Sahara
2 Earth's biggest hot desert, Sahara covers around 9mn km² (3.5mn mi²) in northern Africa. Around 20 per cent is sand dunes, which can be taller than the Eiffel Tower.

Arabian
3 Summer temperatures in the Arabian Desert can reach 54°C (129°F). It covers 2.3mn km² (900,000mi²) of the Arabian Peninsula, mainly in Saudi Arabia.

Gobi
4 The rocky Gobi Desert covers 1.3mn km² (500,000mi²) of Mongolia and China. Temperatures range between 45°C (113°F) and -40°C (-40°F) in a year.

Kalahari
5 The Kalahari basin has Earth's biggest diamond mines. This southern African desert covers over 900,000km² (350,000mi²) and almost 70 per cent of Botswana.

The biggest iceberg on record was the size of Jamaica. It calved off the Ross Ice Shelf in 2000

The smallest icebergs are called growlers. Slightly bigger bergs are 'bergy bits' and the biggest are 'very large bergs'.

The resilie[illegible]

In contrast, the Southern Ocean encircling Antarctica is among Earth's most biologically rich oceans. The melting of sea ice in the spring draws nutrient-rich waters from the depths, feeding phytoplankton. Incredibly, a litre (0.3 gallons) of water can contain more than a million of these tiny life forms.

The phytoplankton are eaten by krill, the powerhouse of Antarctica's ecosystem. These shrimp-like creatures can grow to six centimetres (2.4 inches) long and form swarms big enough to see from space. They are the food source for most Antarctic predators, including the blue whale – Earth's biggest animal. During the feeding season, a blue whale can consume 40 million krill on a daily basis! ▶

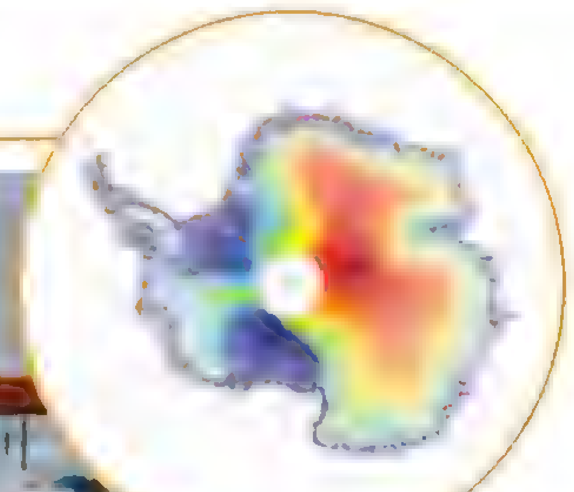
Antarctica's climate explained

Antarctica is Earth's largest desert, but is covered by kilometres of frozen water. Snowfall accumulates because it can't melt in the cold, but yearly snowfall equals less than 50 millimetres (two inches) of rain. Few clouds form in the dry air. All deserts receive less than 250 millimetres (ten inches) of annual rain.

It's also Earth's windiest continent. The ice reflects away 80 per cent of incoming sunlight, cooling the overlying air, which sinks. This heavy air gusts downhill at speeds exceeding 200 kilometres (124 miles) per hour. Summer temperatures rarely rise above freezing, even at the coast.

The continental interior is colder (around -20°C/-4°F in summer) because it's mountainous and farther from the ocean. Winter temperatures there plummet so low, they could freeze diesel.

Air temperatures have remained stable over Antarctica since the Fifties, except for the Antarctic Peninsula. This peninsula juts into the ocean and is among Earth's fastest-warming places.



Scientists in Antarctica have to cope with some extreme conditions

Tour of the frozen continent

Mount Vinson
Just over 1,000 climbers have scaled Mount Vinson in the Ellsworth Mountains, Antarctica's highest summit – fewer than have climbed Everest. The massif is 4,892m (16,050ft) above sea level. Despite 24-hour sunlight, the average summer temperature is -30°C (-22°F).

Larsen Ice Shelf

Weddell Sea

Pine Island Glacier

Halley VI
This British research station has hydraulic legs to 'climb' from the 1.2m (4ft) of snow that builds up annually. The station can be towed inland on giant skis fitted to the legs so it won't float off on an iceberg as the Halley ice shelf moves into the sea.

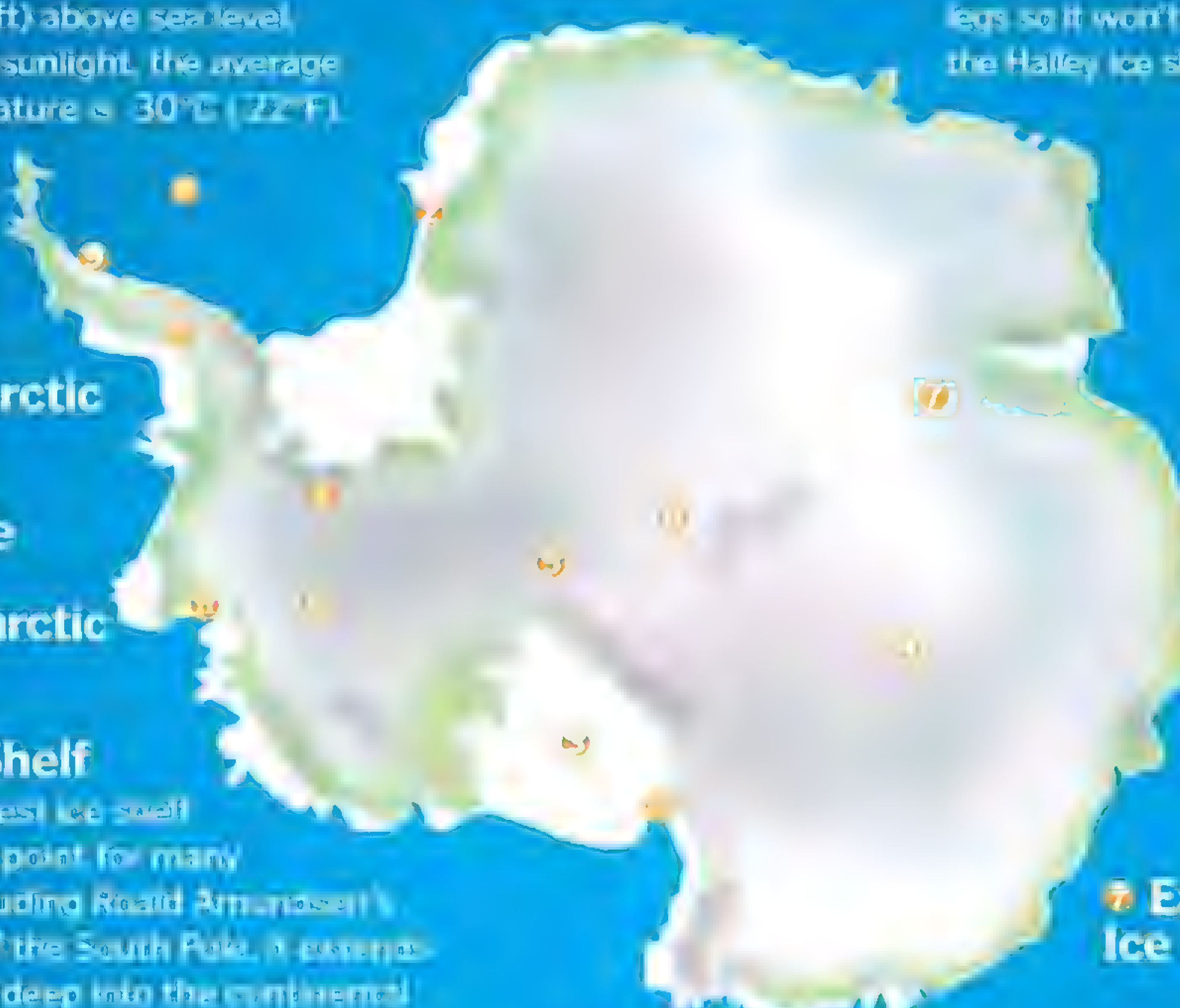
Antarctic Peninsula

Transantarctic Mountains

South Pole

West Antarctic Ice Sheet

Ross Ice Shelf
The world's biggest ice shelf was the starting point for many expeditions, including Roald Amundsen's 1911 discovery of the South Pole. It extends 950km (600mi) deep into the continental interior. It covers over 472,000km² (182,000mi²) – an area bigger than Japan.



Lake Vostok
The icy, dark waters of Antarctica's biggest sub-glacial lake could be teeming with life, despite being buried 4km (2.5mi) beneath the ice for millions of years. In July 2013, scientists revealed that ice collected near the lake waters contained genetic material from 3,507 critters, including bacteria.

East Antarctic Ice Sheet

McMurdo Dry Valleys

Seasonal variation
During the winter the formation of sea ice around Antarctica essentially doubles the size of the continent compared to summer, from about 18.1 million square kilometres (7 million square miles) to 33.7 million square kilometres (13 million square miles). The ice can grow at a rate of 103,600 square kilometres (40,000 square miles) per day!

> "Fossilised pollen even shows that rainforests grew on the continent around 52 million years ago"

Most of the world's seals also live in Antarctic waters. These carnivorous mammals live, hunt and can even sleep underwater. Elephant seals also hold the record for having the biggest relative size difference between males and females of any mammal.

The most common birds in this frozen land are penguins, though of Antarctica's 17 species, only five breed on the continent itself. Emperor penguins – the world's tallest, largest penguin – live exclusively in the Antarctic. Males go without food for nine weeks during winter while incubating their eggs, and the females make a long, perilous journey to seek food for when the chicks hatch.

Islands in the Southern Ocean, surrounding Antarctica are wetter, milder and have more varied vegetation than the mainland. Bird Island, South Georgia, for example, has an average summer temperature of four degrees Celsius (39 degrees Fahrenheit). Its dominant coastal vegetation is tussock grass, which can grow to two metres (6.6 feet) tall.

Even Antarctic icebergs can be home to life. Young icefish hide from predators in holes in the ice. Snow petrels also nest on the bergs, which are generally safer than the mainland.

Antarctica was not always an icy desert. Dinosaurs and other megafauna lived in Antarctica when it was warmer. For instance, fossils of a car-sized armadillo, which lived around 45 million years ago, were discovered near the Antarctic Peninsula. Fossilised pollen evidence even shows that rainforests grew on the continent around 52 million years ago, but eastern Antarctica began to freeze over some 34 million years ago, when Earth's climate cooled dramatically.

How icebergs form

In November 2013, the ice shelf attached to Antarctica's Pine Island Glacier shed an iceberg the size of Singapore. Gigantic ice shelves fringe 30 per cent of the Antarctic coast, and thousands of huge blocks of ice break off each year.

Icebergs can be streaked green by algae growing beneath them or bluish if they're made of compacted ice, which scatters lots of blue light.

They float because ice is less dense than the surrounding seawater. As water freezes, the molecules spread out into ice crystals. The crystals fill more space than seawater, but have identical mass, making them lighter.

Glacier
Snow builds up in Antarctica's continental interior until it slides downhill under its own weight, forming an ice stream.

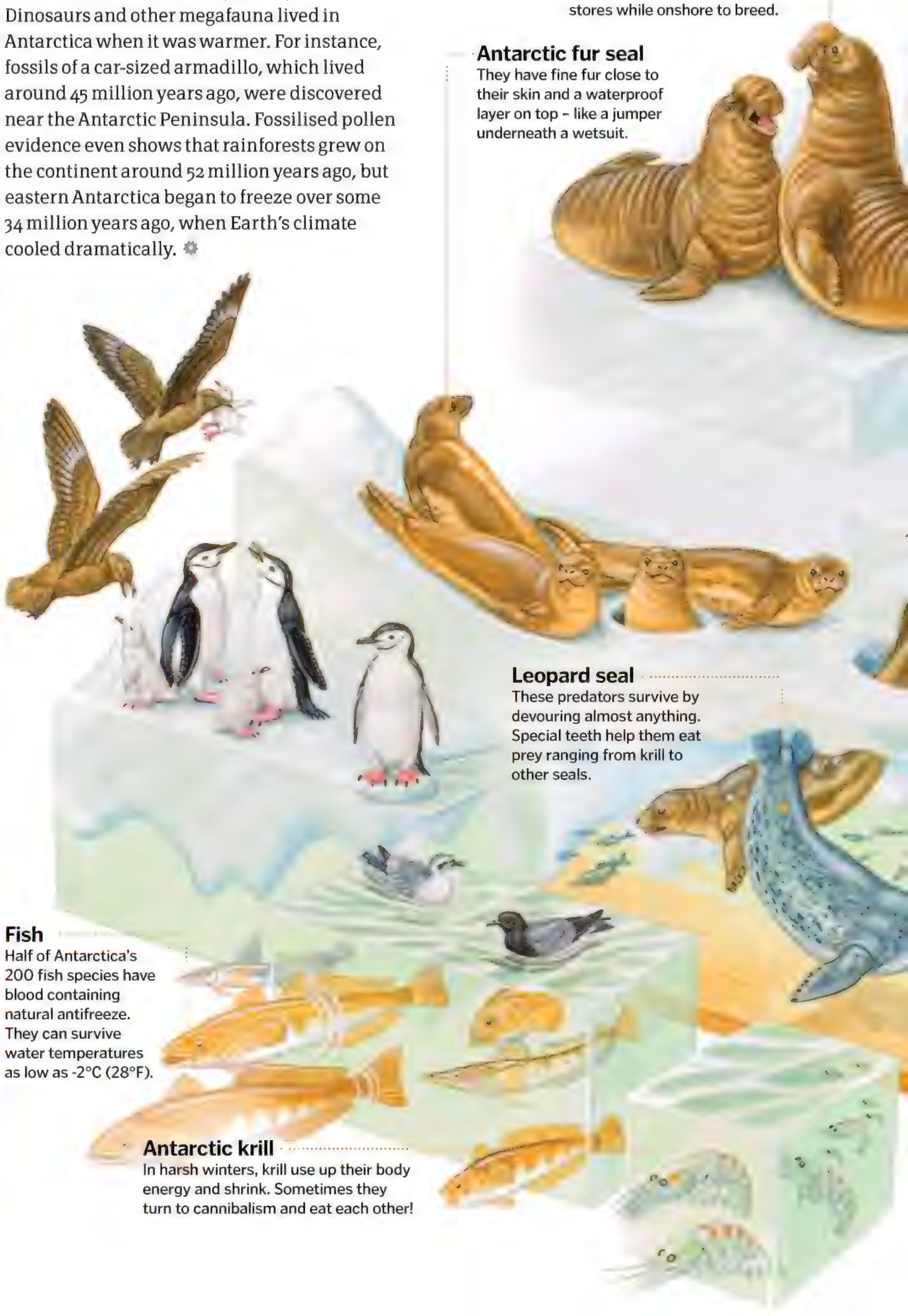
Ice shelf
When the glacier reaches the coast, it won't stop there, but extends into the sea to form a floating platform called an ice shelf.

Ocean
The ocean's tidal motion raises and lowers the ice shelf, causing cracks. Warm seawater melts and weakens the shelf bottom from below.

Iceberg calving
Chunks of ice break off the shelf and crash into the ocean, creating huge waves. Icebergs are born.

Life in the freezer

Discover how a wide range of wildlife has adapted to the bitter Antarctic terrain

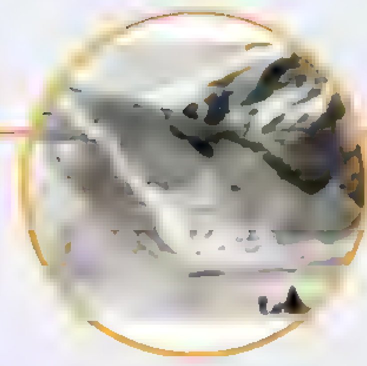


KEY DATES
ANTARCTIC EXPLORATION

1772
James Cook sets sail for the Antarctic Circle, realising rock-strewn icebergs came from an undiscovered continent.

1911
Norwegian Roald Amundsen becomes the first to reach the South Pole, beating the British explorer Robert Scott.

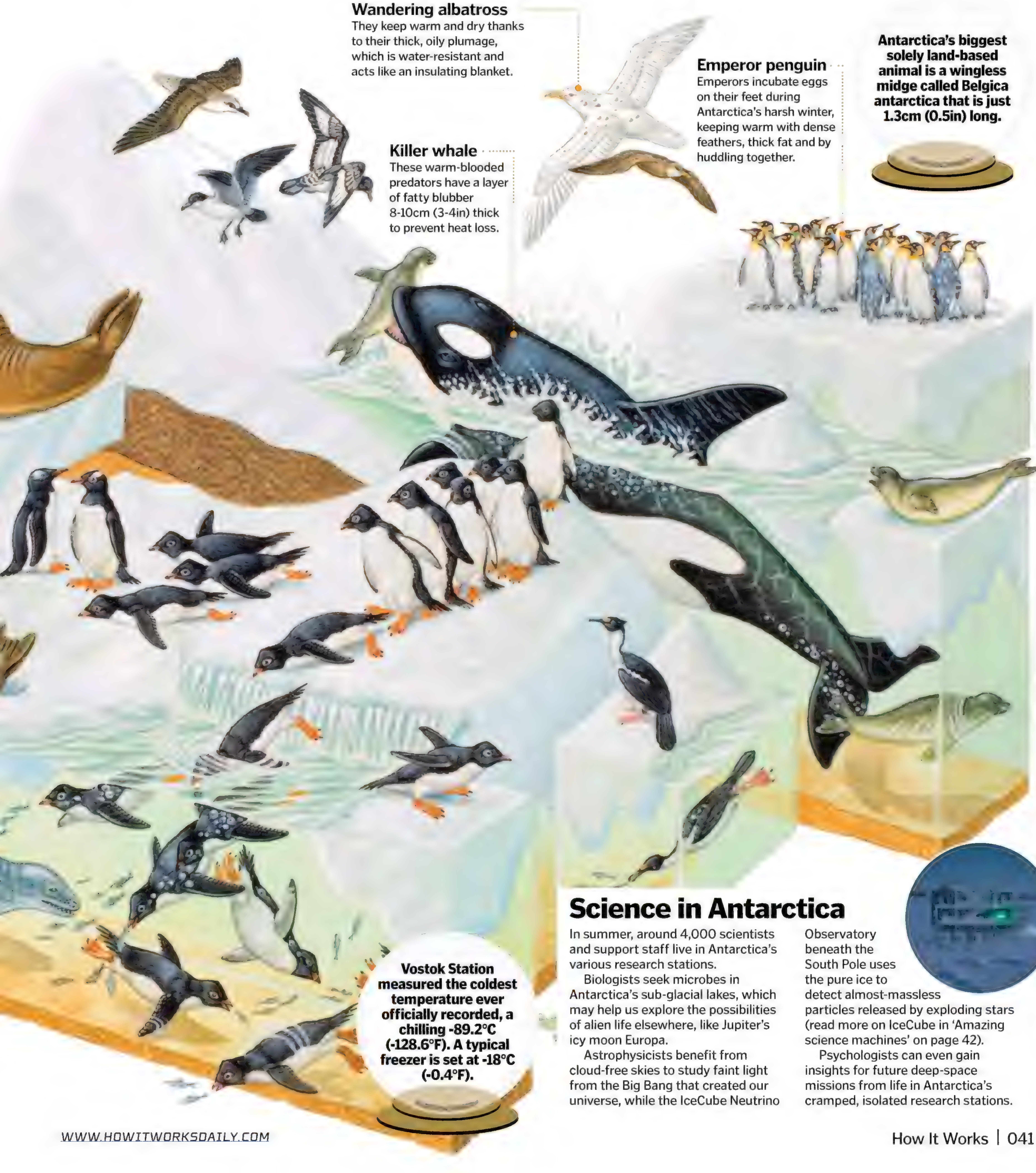
1914
Ernest Shackleton attempts to cross Antarctica, but is stranded for almost two years after winter ice crushes his ship.



1929
US explorer Richard Byrd is the first to fly over the South Pole. He goes on to lead five expeditions to map Antarctic territory.

1996
Borge Ousland makes the first unassisted solo crossing of Antarctica towing a 180kg (400lb) sled with skis and a sail.

DID YOU KNOW? Blue whales are the largest ever-known animal. As heavy as 24 elephants, they mainly eat paperclip-sized krill



Science in Antarctica

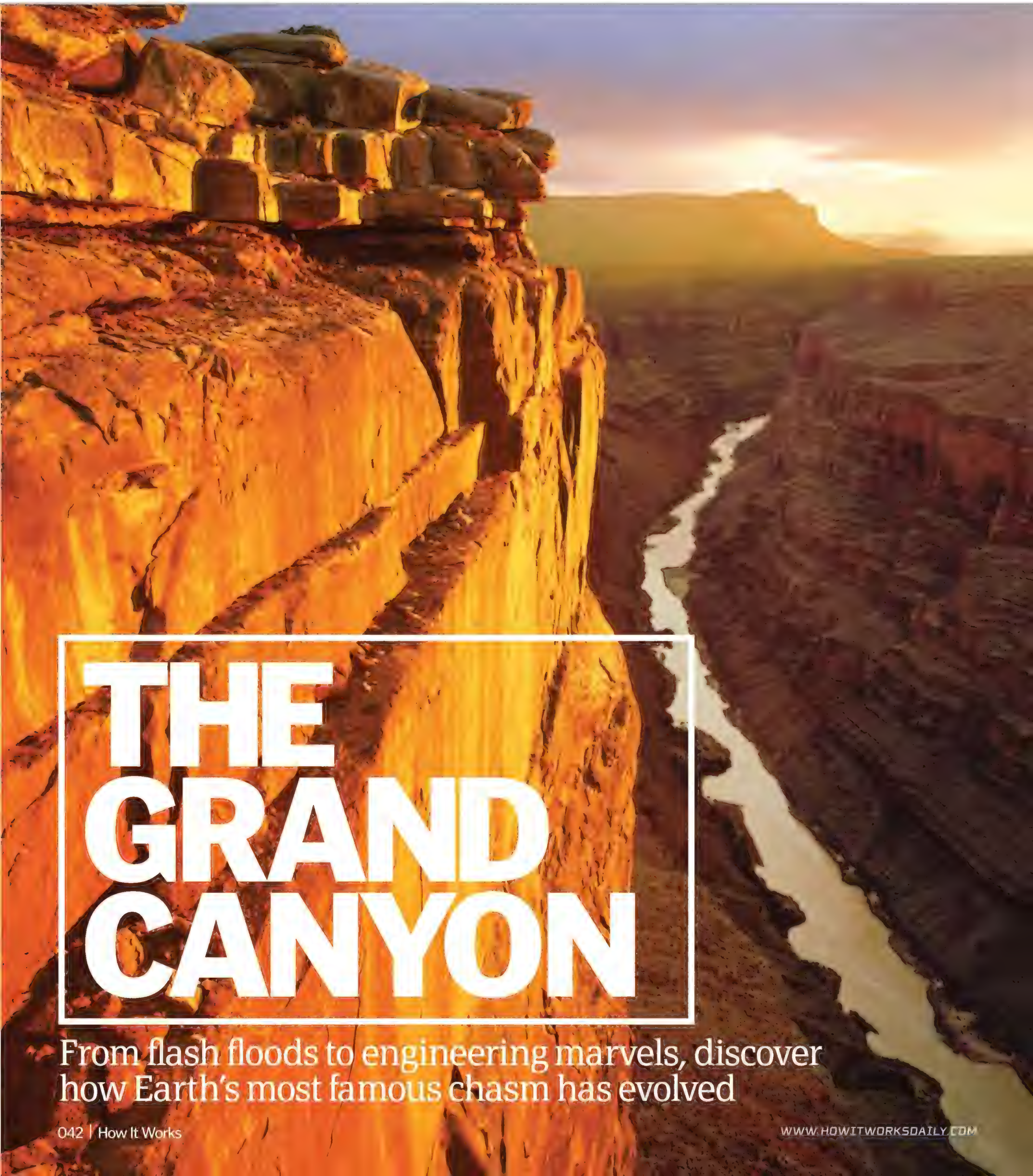
In summer, around 4,000 scientists and support staff live in Antarctica's various research stations.

Biologists seek microbes in Antarctica's sub-glacial lakes, which may help us explore the possibilities of alien life elsewhere, like Jupiter's icy moon Europa.

Astrophysicists benefit from cloud-free skies to study faint light from the Big Bang that created our universe, while the IceCube Neutrino Observatory beneath the South Pole uses the pure ice to detect almost-massless particles released by exploding stars (read more on IceCube in 'Amazing science machines' on page 42).

Psychologists can even gain insights for future deep-space missions from life in Antarctica's cramped, isolated research stations.

"The youngest rocks are about 270 million years old"



THE GRAND CANYON

From flash floods to engineering marvels, discover how Earth's most famous chasm has evolved

5 TOP FACTS GRAND CANYON LANDMARKS

Havasu Falls
1 The turquoise waters of Havasu Creek plunge 30m (100ft) over red rocks, creating the canyon's most striking waterfall. The spectacular colour comes from dissolved magnesium.

Lava Falls
2 Among Earth's best-known rapids, boats drop some 4m (13ft) in churning waters. The Colorado River is constricted by debris at the falls and rushes through the narrow channel.

Angel's Window
3 This mammoth natural arch is high on the North Rim and offers views over the Colorado River. The wedge-shaped hole was created by wind and water eroding weaker rocks.

Desert View Watchtower
4 This fake ruined tower and curio shop gives sweeping views of the canyon. Finished in 1932 in the early days of tourism, it is modelled after Native American watchtowers.

Lee's Ferry
5 The only place for 1,120km (700mi) where you can drive down to the Colorado River. Native Americans, miners and pioneers made ferry crossings here from 1872 to 1928.

DID YOU KNOW? *Flash floods can tear through narrow canyons at speeds exceeding 7m/s (23ft/s) – faster than most cyclists!*

The Grand Canyon on the Colorado Plateau in south-west USA is among our planet's most spectacular natural wonders. The proportions of this colourful crevice in the Earth are mind-boggling, reaching as deep as 1.6 kilometres (one mile) – easily enough to fit four stacked Empire State Buildings. It stretches an average 16 kilometres (ten miles) from rim to rim – equivalent to the length of 176 football fields.

You'd expect a canyon this big to take millions of years and a geological cataclysm to form. But surprisingly, the Grand Canyon was created by the Colorado River steadily cutting into the Colorado Plateau. Scientists believe this erosional process began 5 or 6 million years ago – which is a blink in geological time.

Stare into the canyon and you can see countless rock layers. Their striking colours are due to rainwater washing minerals down the cliffs. The canyon's dramatic step-stair profile is caused by wind and water eroding weaker rock layers. Some rocks, like shale, are easily worn away while others, such as granite, are much more robust.

The canyon rocks are older than the canyon itself. The limestone cliffs directly below the rim formed 270 million years ago. As much as 1.6 kilometre (one mile) of younger rocks covered them, but were worn away over millennia. Remnants of these younger rocks exist near the Grand Canyon; Red Butte, for example, was protected from erosion by a cap of hard lava.

LONG DRIVE
It takes five hours to drive between the South and North Rim Villages, as the canyon is in the way!

The canyon's importance is not limited to its geology. Elevation ranges from 760 metres (2,000 feet) at the bottom to over 2,440 metres (8,000 feet) on the North Rim, creating vast differences in temperature and rainfall.

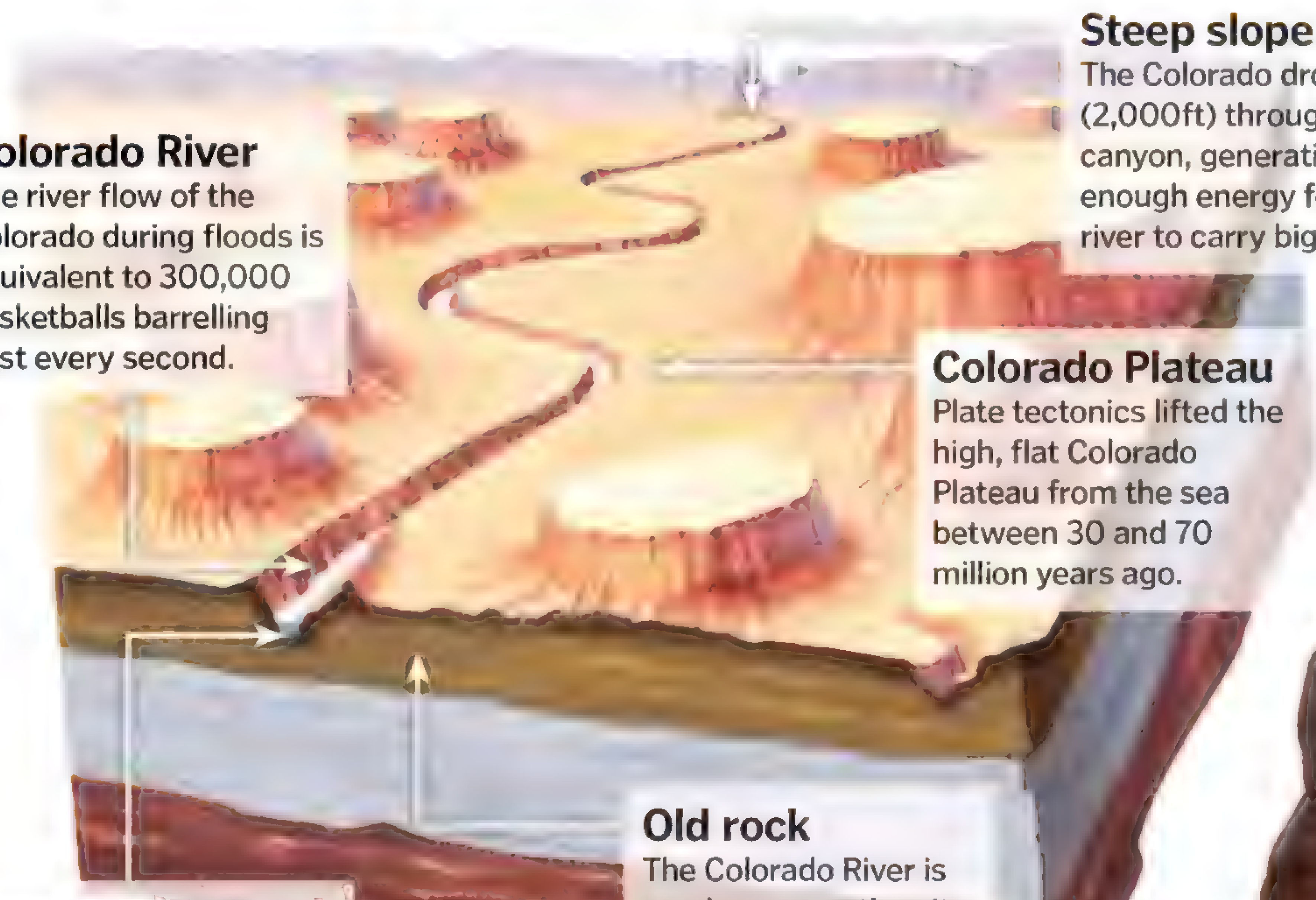
The highest temperatures are at the canyon bottom. Temperatures rise by around ten degrees Celsius per kilometre (29 degrees Fahrenheit per mile) descended. Bright Angel Ranger Station, the coolest and wettest weather station, is less than 13 kilometres (eight miles) from Phantom Ranch, the hottest and driest. The coolest temperature recorded was -30 degrees Celsius (-22 degrees Fahrenheit) on the North Rim, while the warmest temperature clocked in at 49 degrees Celsius (120 degrees Fahrenheit) at Phantom Ranch.

Beyond temperature, precipitation radically varies across the site. Lee's Ferry is the driest station in the park, with only 15.5 centimetres (6.1 inches) of rainfall on average per year. Compare this to the North Rim, which receives 3.6 metres (12 feet) of snow annually.

The arid climate often results in flash flooding. In late summer, clouds build in the clear skies. Ground heating creates updraughts of warm air that climb several kilometres; if the air is moist, violent thunderstorms ensue. The parched ground cannot absorb the rainfall, meaning a wall of water up to 15 metres (50 feet) deep can sweep down creeks and dry channels, collecting debris. ▶

Canyon in the making

What did the Grand Canyon look like in its early days?



Steep slope
The Colorado drops 610m (2,000ft) through the canyon, generating enough energy for the river to carry big boulders.

Colorado River
The river flow of the Colorado during floods is equivalent to 300,000 basketballs barrelling past every second.

Colorado Plateau
Plate tectonics lifted the high, flat Colorado Plateau from the sea between 30 and 70 million years ago.

Old rock
The Colorado River is much younger than its surrounding rocks and took its present-day course about 5-6 million years ago.

Downcutting
The river cuts down into the plateau during floods. Large boulders act as chisels, chipping down through the riverbed.

Rock layers exposed

Glimpse in the Grand Canyon and you'll spy countless layers of different coloured rocks. They form a geological history spanning almost 2 billion years.

The inner canyon rocks formed approximately 1.8 billion years ago during a collision of the Earth's crustal plates. The intense heat and pressure resulted in the creation of dark garnet-studded metamorphic rocks and volcanic rocks.

On top are layers of sedimentary rocks, laid down in climates ranging from sandy deserts to shallow seas. Many contain fossil sponges, bacteria or armoured fish. The youngest rocks are about 270 million years old – any younger overlying rocks have since been eroded away.

"The varied conditions mean the canyon supports a range of wildlife"

The Colorado River erodes exposed rock walls during floods. The river averages 91 metres (300 feet) wide and 12 metres (40 feet) deep, with a volume equal to 15,000 basketballs rolling past per second, though in the last ice age, volumes may have reached a million basketballs.

The varied conditions mean the canyon supports a huge range of wildlife. Five of the seven North American habitats are found here, including hot desert, desert steppe, open woodland, fir and spruce forest. Such diversity is akin to travelling between Canada and Mexico!

The Grand Canyon National Park is home to over 1,500 plant, 89 mammal, 47 reptile, nine amphibian and 17 fish species. Among them is the California condor, the biggest North American land bird. It roosts inside the canyon's red limestone cliffs and has a wingspan of up to three metres (9.8 feet).

On the surface, coyotes are at the top of the food chain, able to sprint at up to 65 kilometres (40 miles) an hour after their prey. The park is also refuge to species such as mountain lions, while there are a dozen plants found only in the borders of this unique national park.

VARIED HEAT
Temperatures can be simultaneously 21°C (70°F) on the North Rim and a sweltering 38°C (100°F) at the Colorado River below.

Humans have lived in the canyon for over 10,000 years too. They include hunter-gatherers who created rock art and nomads who built semi-permanent villages on canyon terraces.

Today, the canyon receives about 5 million visitors a year and is greatly affected by us. The Glen Canyon Dam blocks the Colorado River 24 kilometres (15 miles) upriver of the canyon. The dam traps 90 per cent of the canyon's annual sediment supply in Lake Powell – the USA's second-largest reservoir. It controls the release of water to generate hydroelectric power, eliminating the enormous spring floods that eroded the plateau.

But the dam has also endangered archaeological resources and reduced fish populations. Among them is the humpback chub, an endangered 4-million-year-old fish.

The canyon is deepening at around 0.1mm (0.004in) annually, but the rate is slowing. The Colorado River has eroded its steep slopes and has less power to cut through hard crystalline volcanic rocks. A few million years in the future, erosion may have deepened it somewhat, but it could have grown too wide to see across.

Life on the edge

Discover how the Grand Canyon's plants and animals adapt to this rugged terrain

Grander canyons

The Grand Canyon is not actually our planet's biggest. Tibet's Yarlung Tsangpo Grand Canyon is considered to be one of the world's deepest. It stretches over 5,300 metres (17,400 feet) top-to-bottom in some places – which is more than three times the depth of America's Grand Canyon.

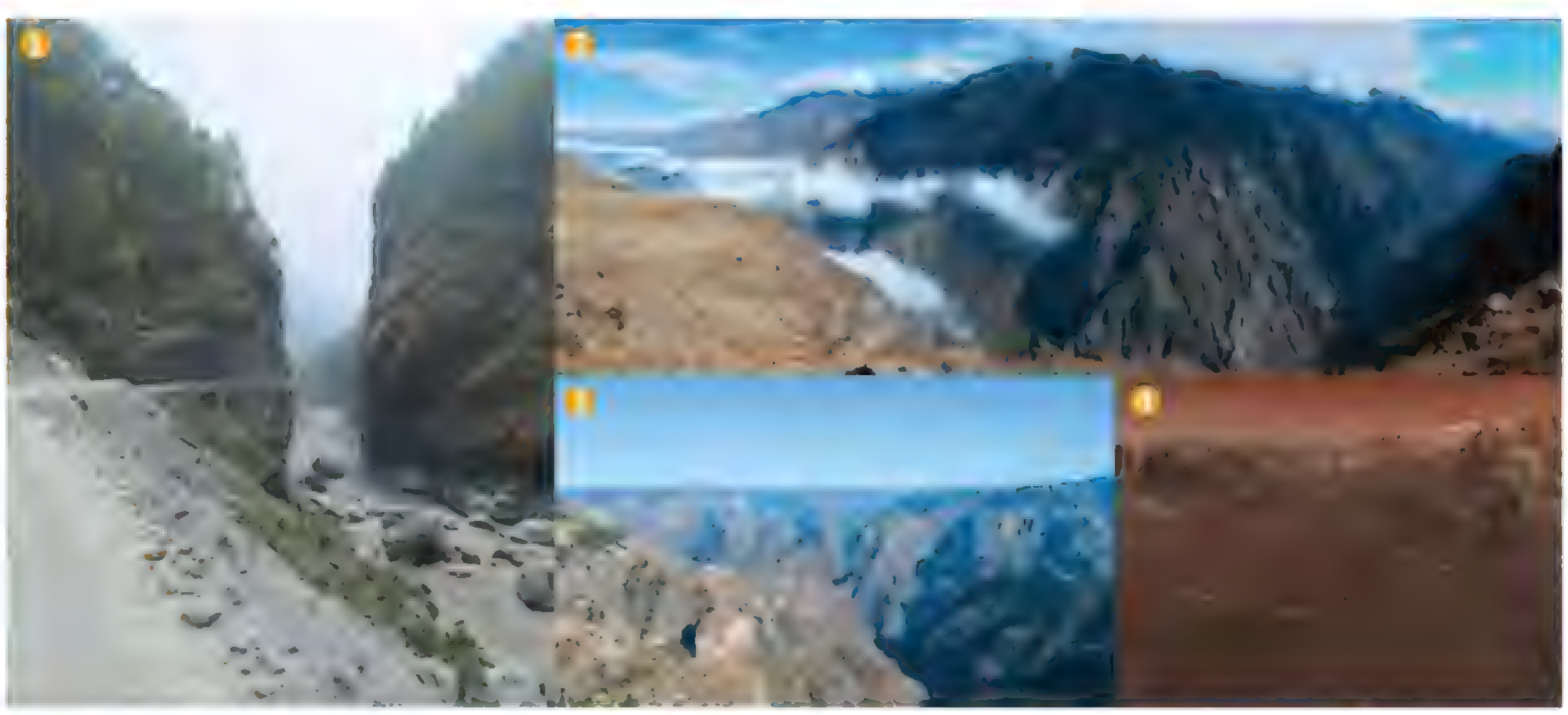
Tsangpo is also among Earth's longest and most inaccessible canyons. In 2002, a seven-person team were the first to successfully kayak the upper gorge. They used satellite images to navigate as there were no maps available.

Another candidate for the deepest gorge is Kali Gandaki Gorge in Nepal 1. Among the shallower canyons is Peru's Colca Canyon 2, which is over twice as deep as the Grand Canyon.

Earth's widest canyon is Australia's Capertee Valley. Copper Canyon in Mexico 3, meanwhile, is a series of canyons that together are more than 100 times longer than the Grand Canyon.

But some of Earth's biggest canyons are hidden, as they lie beneath the sea. For instance, Zhemchug Canyon in the Bering Sea is 60 per cent deeper than the Grand Canyon. And mammoth canyons are still being discovered, like Greenland's Grand Canyon, which was carved by rivers some 4 million years ago, before Greenland was buried by ice.

Off Earth, Valles Marineris on Mars 4 trumps the Grand Canyon on all counts including length, width, depth and age; if it were placed on Earth, it would stretch from Los Angeles to New York.



THE STATS GRAND CANYON

LENGTH **433km** | AVERAGE DEPTH **1.6km** | TOTAL VOLUME **4.2tn m^3** | MAX WIDTH **29km** | NARROWEST POINT **180m** | AGE **>6mn yrs**

DID YOU KNOW? *Sightseeing plane crashes are the main cause of death around the Grand Canyon, with 65 fatal flights recorded*

Walking on air…

The Skywalk is an engineering masterpiece that took four years and $30mn (£18.2mn) to build. This glass-bottomed platform protrudes 21m (70ft) from the canyon rim, offering a stunning view – though not one for vertigo sufferers!

Finished in 2007, the Skywalk was assembled on the West Rim. It took two days to roll it over the canyon, using the same rod-and-plate method as used for the Egyptian pyramids.

Floating 1,200m (4,000ft) above the Colorado, the U-shaped Skywalk is supported by beams anchored deep within the red limestone bedrock, which act as counterweights.

The Skywalk has had 2 million visitors. Each of the walkway's glass panel units can withstand the weight of 800 people, but only 120 visitors are allowed on at a time.

California condor
New World vultures with strong beaks to break dead animal bones. Their bald heads help them keep clean when rooting inside carcasses.

Utah juniper
These bushy trees have an extensive root system to access moisture in the dry environment. They can live for 700 years.

Common raven
Their stocky bodies and water-rich diet of carrion, eggs and plants helps them regulate their body temperature in desert heat.

Barrel cactus
Their barrel-shaped stems are pleated like an accordion and swell to hold water. Curved spines also help to shade the plant.

Mountain cottontail
Limited food and scarce shelter may explain why these rabbits are solitary. They are named for their fluffy cotton-ball tails.

Margarita flowers
A drought-tolerant plant found in shallow and dry soil. It has narrow leaves to minimise water loss.

Beaver-tail cactus
A small prickly pear that grows to around 60cm (2ft) tall. Like all cacti, it stores water in its fleshy stems.

Mountain lion
Human activity forced these big cats to retreat to the rugged uninhabited Grand Canyon. They can measure up to 2.4m (8ft) from nose to tail.

Deadly sinkholes

What causes this lurking menace under the ground that could open up beneath our feet at any moment – and can anything be done to stop them?

In March 2014, a huge hole suddenly opened up in a road intersection in the city of Detroit in the United States. It was nine metres (30 feet) wide and five metres (16 feet) deep. This is a type of geohazard known as a sinkhole. They are the result of unstable cavities in the ground, which are created from soluble bedrock dissolution caused by a change in underground moisture content and water levels. Because of this, these massive pits more commonly appear in the calendar's wetter months. The effect is exaggerated even more when sudden flooding follows a drought as the ground is not saturated and cannot handle the unexpected deluge.

The most common rocks where sinkholes form are limestone, chalk and gypsum – all of which are soluble sedimentary rocks. These minerals are found in the overburden soil that covers caves, ravines and streams – topography known as karst. Chalk and limestone are two of the most common rocks in the world, so sinkholes can virtually open up anywhere.

The places most at risk on Earth are Florida, South Africa and the cave systems of the Mediterranean. In the United Kingdom, the Peak District, Yorkshire and, more recently, the south-east of England are all danger zones.

Dr Vanessa Banks, a hydrogeologist at the British Geological Survey (BGS), claims that the unusually high amount of rainfall in Britain in the winter of 2013 contributed to at least 19 collapse features in Britain in February 2014. The fact that normally only ten or so sinkholes

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Check out the Winter Park sinkhole in Florida!

www.howitworksdaily.com

DID YOU KNOW? 24,671 insurance claims for sinkhole damage were registered in Florida between 2006 and 2010

are reported to the BGS each year shows the adverse effect that the weather had on the British Isles last winter.

As well as the initial effects, which can include vehicles or entire buildings being swallowed up, there can be a number of long-term consequences. Sinkholes can cause flooding by blocking underground water flow – and in extreme cases this can transform previously dry land into bogs and even lakes.

One of the largest sinkholes ever recorded was the so-called Winter Park sinkhole in Florida that appeared in 1981. It caused mass devastation, swallowing two streets of buildings and cars, amounting to over £2.4 million ($4 million) worth of damage. It spanned a massive 107 metres (350 feet) across and 23 metres (75 feet) deep.

Sinkholes can be split into three varieties: subsidence, solution and collapse. Subsidence holes are created when the overburden is thin and only some sediment is above the carbonate rock. Solution is where there is no overburden layer and collapse is when the permeable rock is weighed down by a huge mass of residue.

Collapses can either be instant or slow-forming, depending on the material on the surface. If the covering material is noticeably light and weak – such as sand – small, gradual fissures are formed over time, while if the surface material is denser – like clay – there is more pressure and weight so it will cave in more suddenly. Generally, if it is the roof of an underground cavern falling, the holes are deeper and steeper, while if it is the dissolving of rock under a soil mantle, they tend to be considerably shallower.

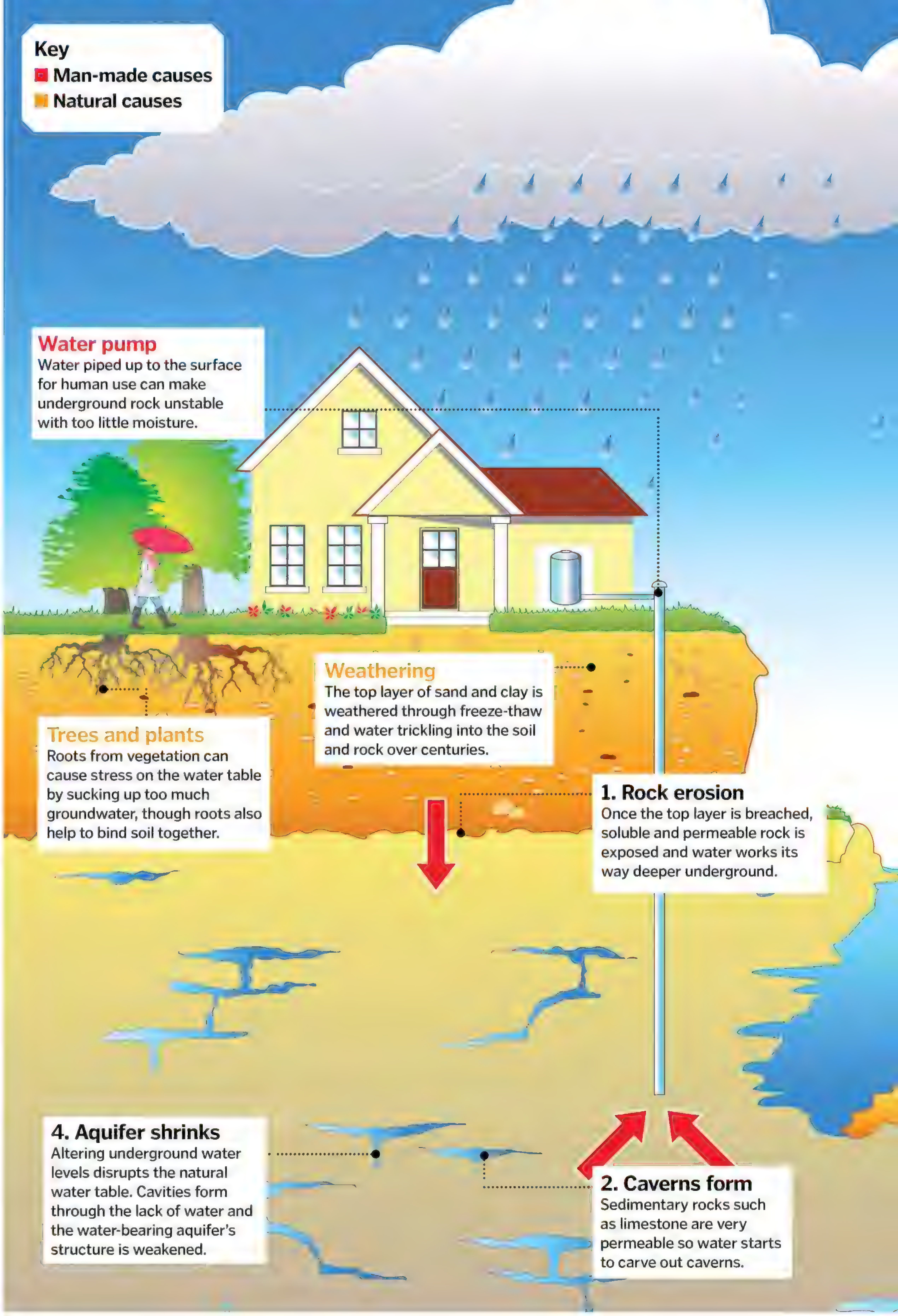
While sinkholes are defined as a collapse over a void of soluble rock, deneholes or 'crown holes' differ. These occur when there is an overburden breakdown over a modern man-made mine, such as a shaft collapse.

As the Winter Park example shows, not all sinkholes occur in the wilderness, with holes evermore frequently opening up in urban areas. The disturbing of groundwater by man-made devices and mechanisms leads to more intense and devastating sinkholes. By altering the natural path of ground water – for instance, in irrigation – we run the risk of exposing soluble rock to more liquid than it can take. In contrast, taking away water for human consumption can open up cavities in the ground and weaken natural foundations.

Above-ground vibration from busy roads and building work can also have a big impact on the

Sinkholes: who's to blame?

Check out the man-made and natural culprits and the process which leads to sinkholes

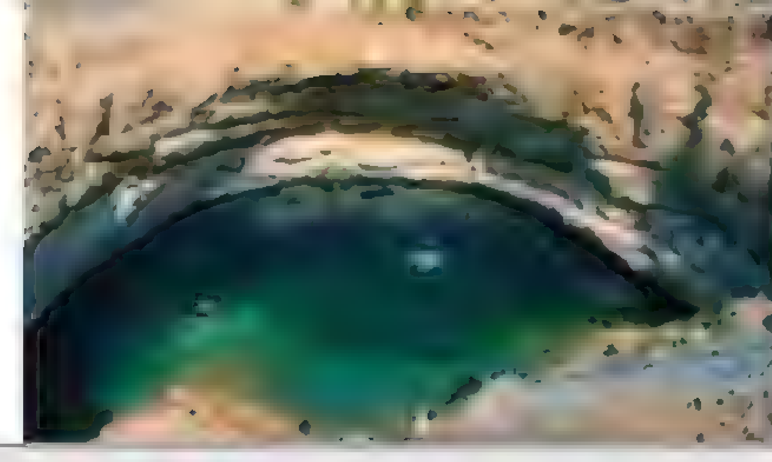


STRANGE BUT TRUE

HOLE-Y ATTRACTION

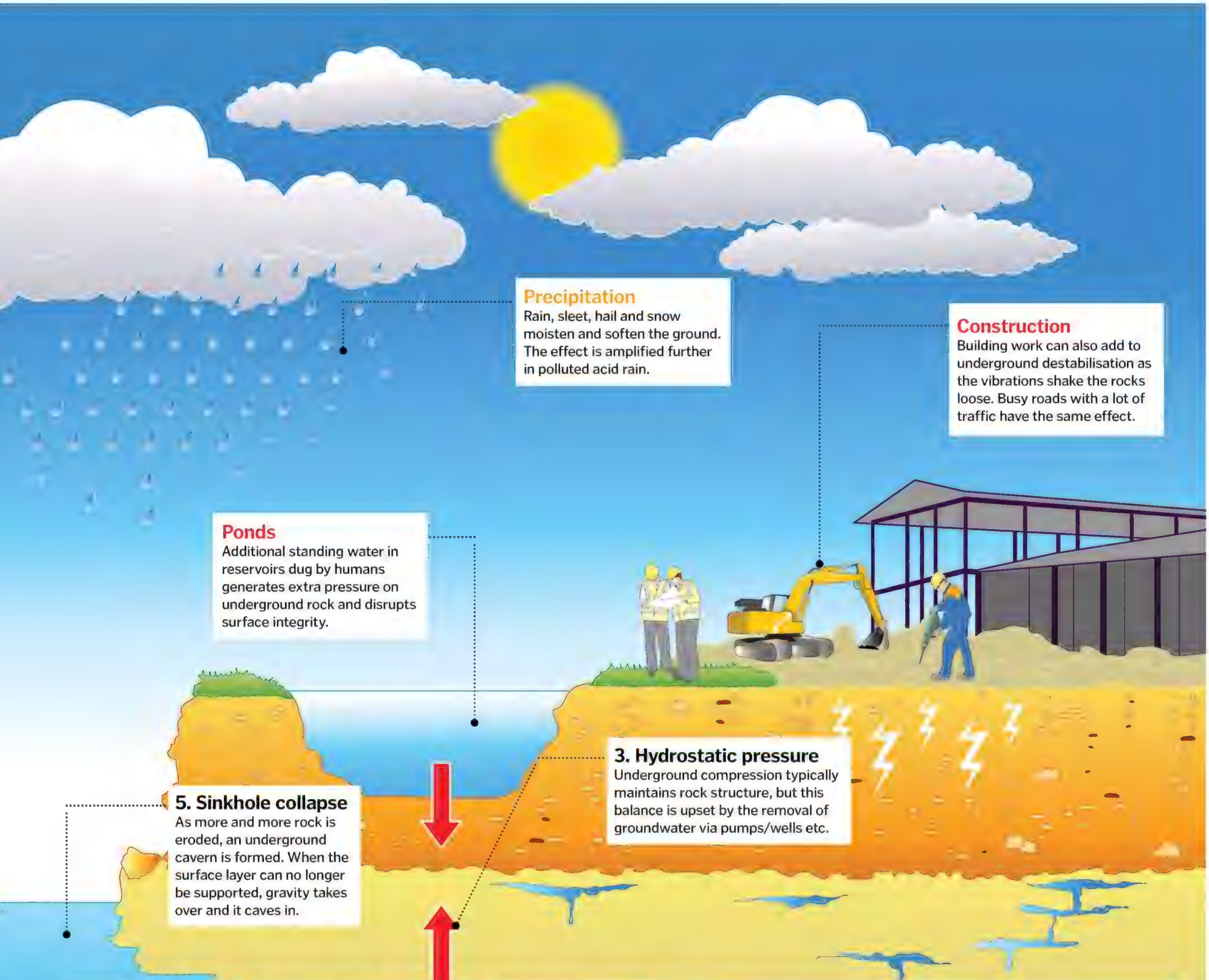
What is the Bimmah sinkhole in Oman used for?

A Landfill B Astronomy C Tourist spot



Answer:
Often portrayed as a natural menace, swallowing cars and buildings whole, the Bimmah sinkhole in northern Oman is a popular tourist attraction within the Hawiyat Najm Park, where many visitors come annually for swimming and camping.

DID YOU KNOW? *Around 20 per cent of the USA lies on karst areas, which are susceptible to sinkholes*



Hunting for sinkholes

How can we spot potential holes before it's too late?

To assess sinkholes, various state-of-the-art techniques are used. 2D electrical resistivity imaging involves electrical currents analysing the hydrogeology of areas. Using electrodes and ground-penetrating radar (GPR), the resistivity of the ground is measured. This creates an image that shows not only the subterranean structure, but also its pores and moisture content. 3D techniques are also employed to result in a better, more accurate image. Another type of imaging system is microgravity imaging. This technique detects tiny variations in the area's gravity, which highlights any cavities and can study up to 50 metres (164 feet) underground. Microgravity is used in tandem with seismic refraction, which provides an image profile of rock types. Combined, they can decipher whether you are dealing with dry cracks or wet, soft, porous soil.

As well as using these conventional techniques, NASA uses airborne radar. Known as InSAR, satellites collect images of ground surface layers that show land deformation, which is a known precursor to possible sinkhole formation. NASA predicts that if data is collected continuously and consistently, they will be able to successfully calculate when, where and to what extent sinkholes will occur in a given area.

"Not all sinkholes occur in the wilderness, with holes evermore frequently opening up in urban areas"

ground's structural integrity. Indeed, the number of human-induced sinkholes has doubled since 1930 as a consequence of both construction and destruction. However, as Dr Vanessa Banks points out, not all rural sinkholes are reported, meaning the notion that more happen in urban areas is slightly flawed due to a lack of rural sinkhole data.

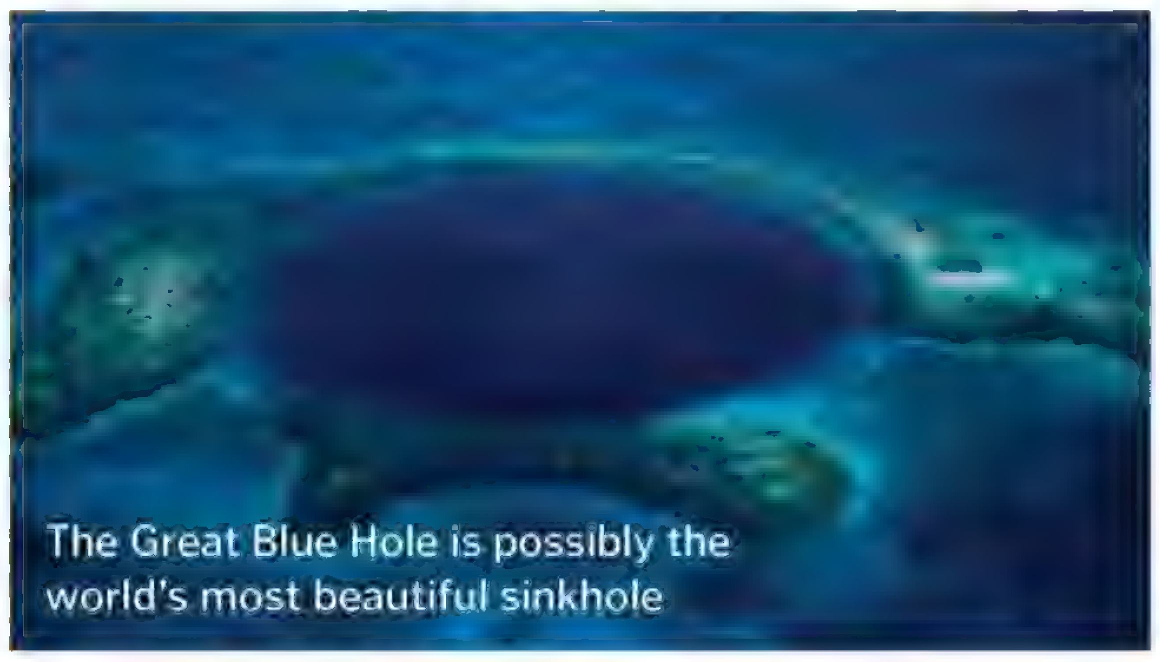
There are a few warning signs to look out for, including slumping and wilting vegetation and cracked walls or foundations. Rain pooling in areas it previously hadn't can also be a telltale sign. If a sinkhole does occur in your proximity, there are a few essential steps you need to take. Engineering geologist Dr Clive Edmonds told us the best course of action:

"It all depends upon the circumstances. If the stability of a building is threatened by a sinkhole occurring beneath it, then contact your insurer and get an experienced geotechnical engineer to quickly action the infilling of the hole to choke it and stop it from expanding laterally and deepening."

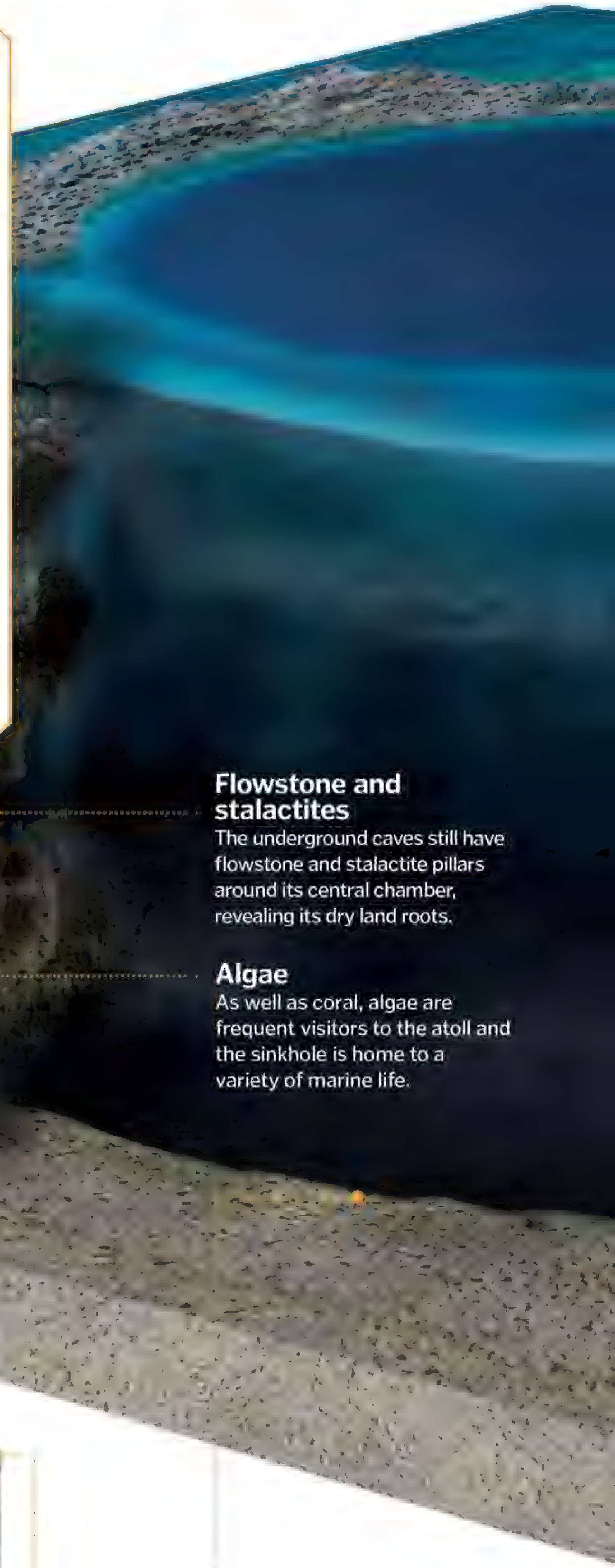
As time goes on, there are new ways to prevent sinkholes from forming. Raft foundation is the use of reinforced concrete slabs to provide an underpinning base that strengthens the ground. Geogrids are made from tough fibreglass with a polymer coating and are an artificial soil structure. A mixture of water, cement and sand creates grout, which is used to combat the development of voids in the soil at specific 'injection points'. This provides a more stable platform for buildings, while reducing the stress on the ground.

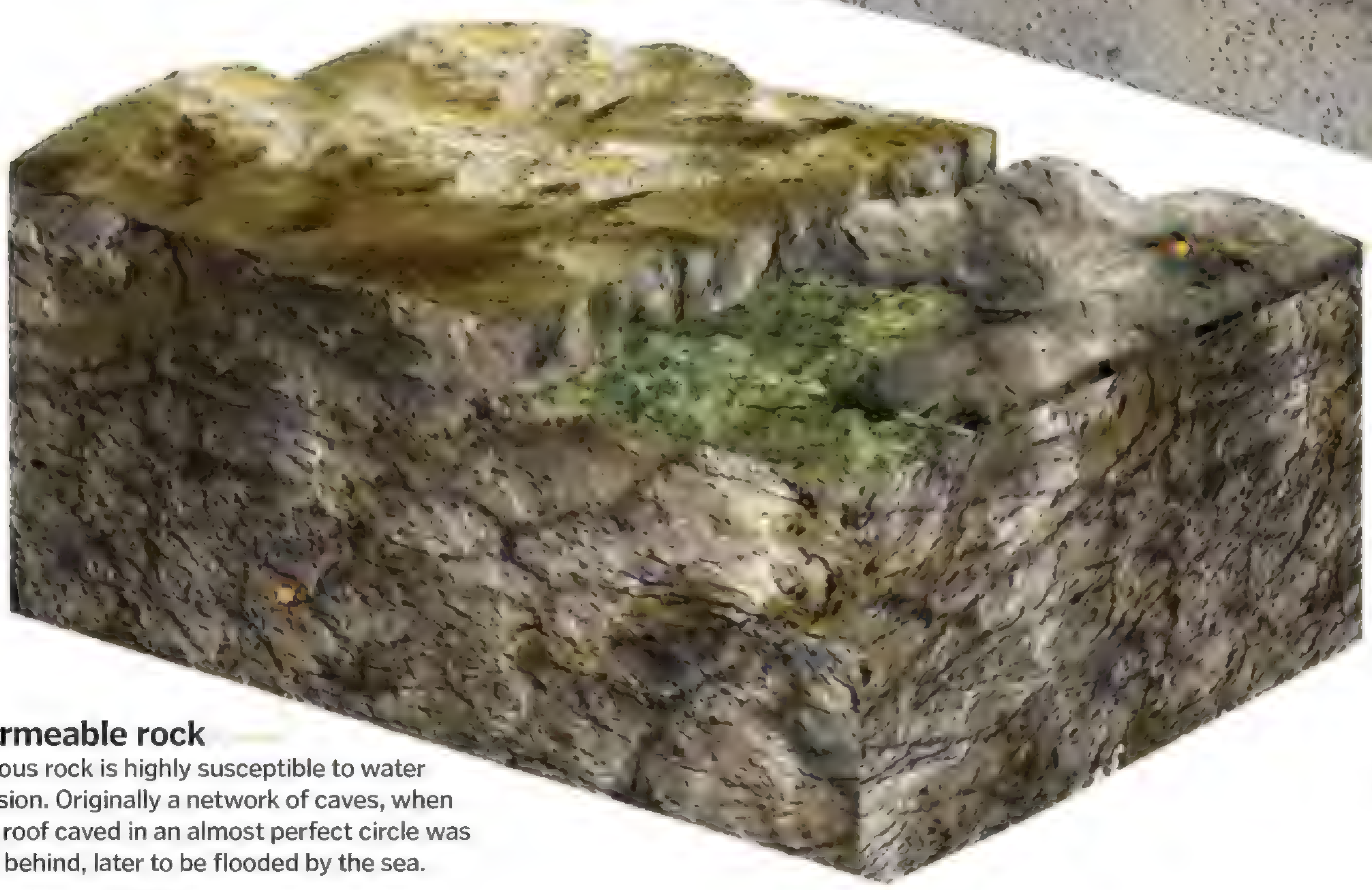
Sinkholes at sea

Lying off the coast of Belize, the Great Blue Hole is the widest ocean sinkhole on the planet. A UNESCO World Heritage Site, it is nestled deep within the Lighthouse Reef Atoll and is a staggering 300 metres (984 feet) in diameter and 125 metres (410 feet) deep. Formed by the falling through of an ancient cave, it used to be on land but rising sea levels thousands of years ago plunged it into the water. Its dry origins are evident in the presence of stalactites, which can only develop on land. Today, the sight is a popular attraction for scuba divers who flock to it from all over the globe.



The Great Blue Hole is possibly the world's most beautiful sinkhole





5 TOP FACTS
FAMOUS SINKHOLES

Ripon, North Yorkshire
1 As recently as February 2014, Ripon in North Yorkshire, Britain, experienced a 7.5-metre (25-foot)-wide hole, where three houses had to be evacuated in a hurry.

Guatemala City
2 In May 2010, a combination of a tropical storm and a volcanic eruption resulted in a huge sinkhole in Guatemala City that swallowed a factory and caused a state of emergency.

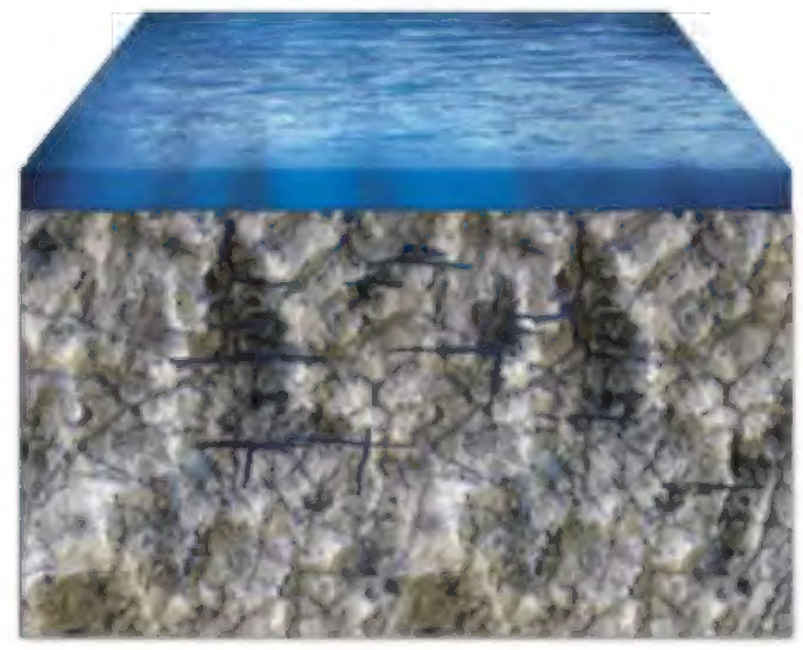
Rocksprings, TX
3 In the rural Rocksprings area of Texas, limestone rocks have caused the formation of the 107-metre (350-foot)-deep Devil's Sinkhole, which hosts over 3 million resident bats.

Slovenia
4 Sinkholes have affected man-made infrastructure in Slovenia. Built over areas of karst, small but frequent caverns regularly waylay construction projects.

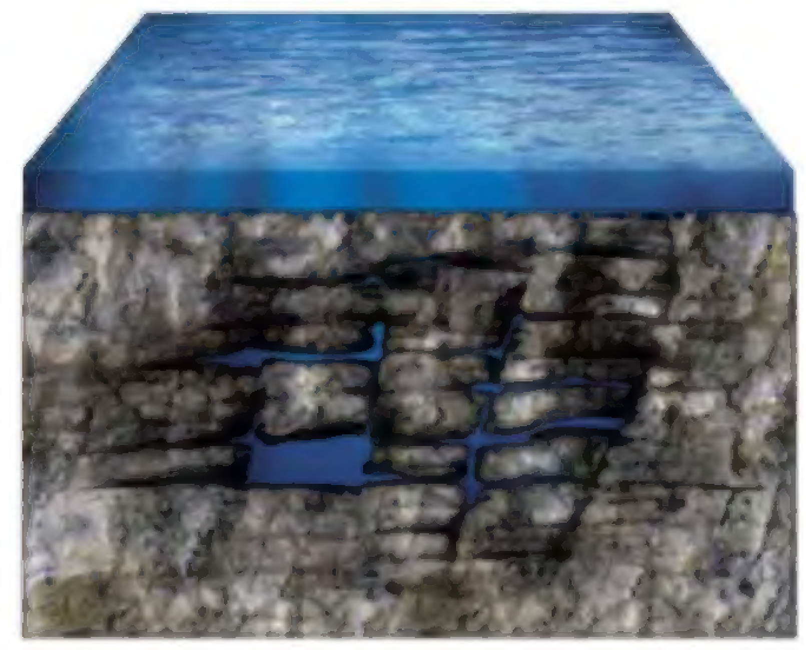
Yucatán Peninsula
5 This area is strewn with limestone sinkholes, or cenotes, that form from collapsed caves and can be up to a stomach-churning 50 metres (164 feet) deep each.

DID YOU KNOW? The Great Blue Hole is the widest but Dean's Blue Hole is the deepest ocean sinkhole at 202m (663ft)

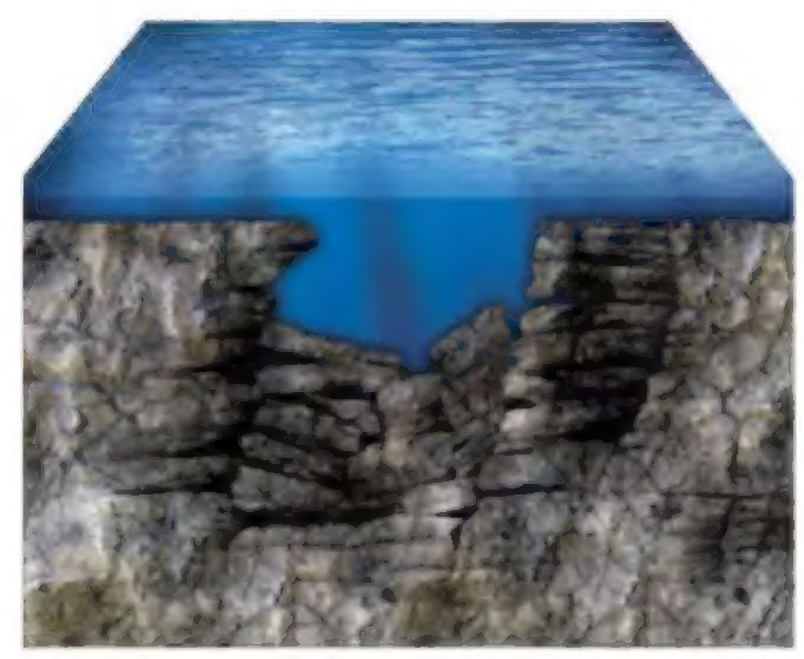
How blue holes are formed



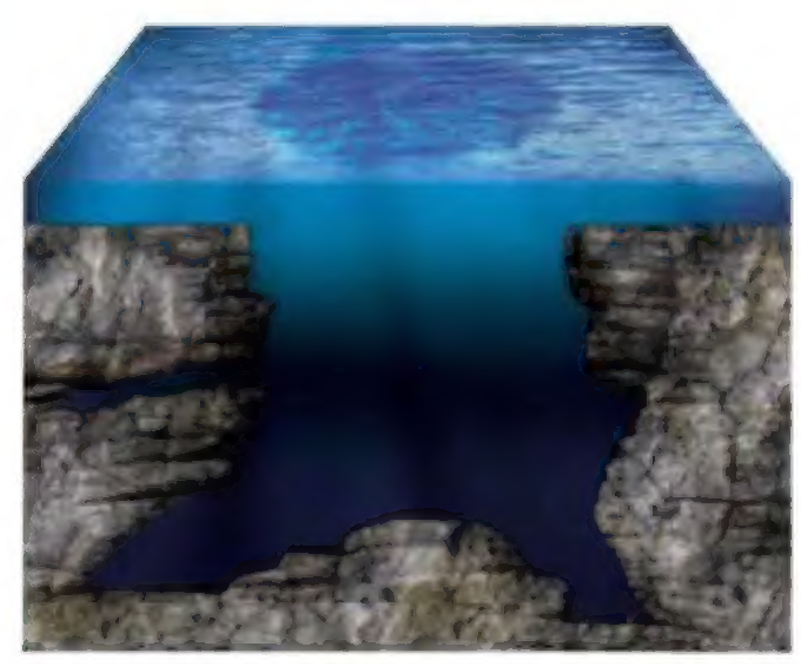
1. Surface erosion
Rain and tidal water gradually eats away an area of hard bedrock, exposing the weaker, soluble carbonate rocks like limestone.



2. Cave network
With no bedrock, the water is now free to corrode the soluble rock. This begins the formation of an underground cavern system.



3. Collapse
The weak limestone is soon dissolved altogether and the cave roof collapses into the crevasse leaving behind a sinkhole.



4. Rise of the ocean
As sea levels rise after an ice age, the area is flooded permanently, creating an ocean sinkhole.

Sinkhole hotspots

One of the most prominent sinkhole areas on Earth is the US state of Florida. This peninsula is dominated by carbonate platforms like limestone that are covered by sand and clay. These soluble materials are battered by erosion and weathering, resulting in a lot of hazardous topography in the Sunshine State. The karst geology was formed after lowering sea levels during the last ice age created new reclaimed land, which had high underground water levels. The underground water reacts with carbon dioxide to form carbonic acid, which erodes the soluble soil and rock. With this topography making water a constant feature, sinkholes are regularly present in the wetlands and Everglades of Florida. Another suffering area is the Dead Sea; the sea is rapidly drying up, partly as a result of heavy irrigation, opening up sinkholes all over the region.

Sinkholes emerge all over Florida, like this one outside the city of Live Oak

ON THE MAP

Major sinkholes around the globe

1. Great Blue Hole, Belize
2. Winter Park, Florida
3. Qattara Depression, Egypt
4. Ripon, North Yorkshire, UK
5. Guatemala City
6. Xiaozhai Tiankeng, China
7. Devil's Sinkhole, Texas
8. Bimmah sinkhole, northern Oman

"Over 30,000 years, it has slowly dried up, leaving behind a huge level plain covered in a thick crust of salt"

World's largest salt flat

The vast expanse known as Salar de Uyuni in Bolivia is a stunning sight to behold, but how did this massive salt flat develop?

When rainfall and melted snow drain down from mountains, they dissolve many minerals from the rocks. Generally, these are washed into the sea, adding to its salinity. Sometimes, however, the water drains into low-lying basins inland, forming salt lakes. If the climate is hot, with long dry seasons, water can evaporate from these lakes over centuries, leaving behind expanses of dried salt, called salt flats.

On the edge of the Andes Mountains of South America, the Altiplano is a vast plateau some 3,650 metres (12,000 feet) above sea level. At the top of the plateau lies a large, flat region, surrounded by higher land, in which a vast prehistoric salt lake formed. Over the last 30,000 years it has slowly dried up, leaving behind a huge level plain covered in a thick crust of salt, called Salar de Uyuni. This covers a staggering 10,582 square kilometres (4,086 square miles), making it Earth's biggest salt flat.

Tour of Salar de Uyuni

A varied landscape around the Salar offers a stark contrast to the white expanse of salt

Incahuasi Island
A few dark 'islands' rise above the salt plain – the remains of ancient volcanoes. The largest, Incahuasi Island, is covered in spiny cacti.

San Pedro de Quemes
This village of about 570 inhabitants at the south-west corner of the flats is surrounded by high volcanic mountains, forming the border between Bolivia and Chile.

A view across the vast, flat Salar de Uyuni, toward the dormant Tunupa volcano

Salt flats layer by layer

The salt crust of Salar de Uyuni is covered in cracks. It covers a layer of muddy soil saturated with brine, which wells up through the cracks. Beneath this are successively older bands of salt and sediments. As well as sodium chloride (salt), the brine contains the chlorides of potassium, lithium and magnesium. Lithium is valuable as a component of the batteries used in laptops, mobile phones and electric cars. 5 million tons of it could lie under the Salar, but the Bolivian government is cautious about developing it, fearing damage to the environment and local communities.

5 TOP FACTS
SALAR DE UYUNI

View from the Moon
1 When Neil Armstrong and Buzz Aldrin first walked on the Moon on 20 July 1969, they spotted the vast white expanse of Uyuni, although at the time they mistook it for a glacier.

Salty accommodation
2 In 1995, a hotel was opened on the Uyuni salt flats built entirely from blocks of salt. It was closed in 2002 because of growing concerns about sewage pollution.

Crumbling crust
3 In places, the salt crust is a few tens of centimetres (1-2 feet) thick. Visitors have died from heat stroke when their vehicles became trapped by this crumbling crust.

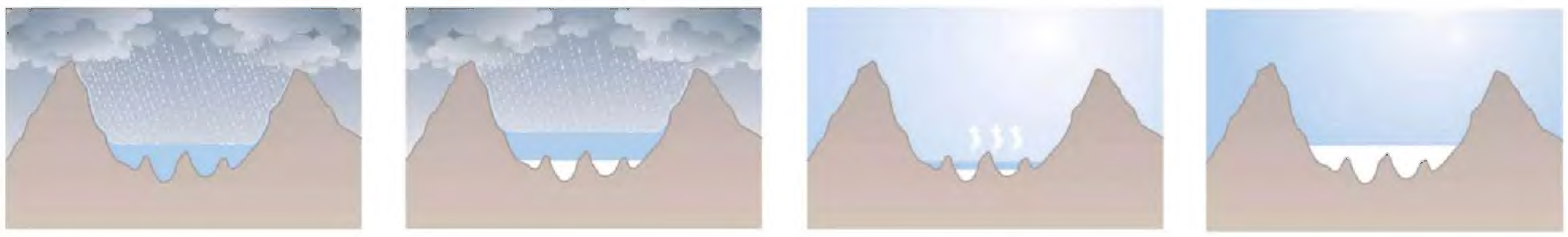
Flat as a pancake
4 Salar de Uyuni is the flattest place on Earth. It is so flat that scientists use its surface to calibrate the altimeters of ground-surveying satellites when they fly overhead.

Flamingo food stop
5 Brine shrimp survive dry periods as eggs and multiply rapidly when the saltwater returns. Three species of flamingos gather in the wet season to feast on the shrimp.

DID YOU KNOW? *Salar de Uyuni is estimated to contain 10bn tons of salt, but only around 25,000 tons is extracted annually*

The vanishing lake

See how Uyuni transformed from a huge lake to a salty plain over 30,000 years



Altiplano rises
The Altiplano is formed with the rise of the Andes Mountains in the Cretaceous period (circa 138-65 MYA).

Lakes form
The vast depression in the Altiplano's flat top begins to fill with water to form a series of lakes. Salt erodes from the local terrain.

Rise and fall
Dating of shells suggests 32,000 years ago there is a deep lake, but its water level fluctuates with rainfall and evaporation.

Lago Tauca
Lago Tauca developed up to 18,000 years ago. Since then, steady drying has left behind layers of salt and mud: Salar de Uyuni.

Harvesting salt in Uyuni

Salt is a valuable commodity, used to flavour and preserve food – and also to keep roads ice-free in winter. The chemical industry also uses it to produce chlorine, caustic soda and sodium hypochlorite. In saltworks, shallow pools are filled with salty water, then left to evaporate in the Sun and wind, but at Salar de Uyuni, salt can be harvested directly from the natural salt flats, speeding up the process.

"Four decades later the gas continues to blaze, lighting up the surrounding region for miles"

Who opened the Door to Hell?

How It Works explores a gas crater in Turkmenistan which has been burning nonstop since 1971

The Derweze natural gas crater is a basin 70 metres (230 feet) across located in the middle of the Karakum Desert in Turkmenistan. The crater, which was created when a natural gas drilling rig and camp collapsed in 1971, is informally referred to by the local people as the 'Door to Hell', as for the past 42 years it has been on fire.

The flames were instigated when a Soviet Union drilling team decided that, after their rig collapsed, the best way to deal with the large amount of methane gas spilling out into the environment was to burn it off. Geologists at the time predicted that the methane would combust within days, but four decades later the natural gas continues to blaze, lighting up the surrounding region for miles.

Today, the Door to Hell is something of a tourist attraction, with travellers flocking to the nearby village of Derweze – which has a population of only around 350 people – from all over the world. Typically tour groups venture to the site in the evening, as the crater's fiery glow is more dramatic in the low light of dusk than during the day, as shown here.